

Contract No. NAS 9-15407
DRL No. T-1373
Line Item No. 5
Report No. ED-AX-147

NASA CR-

160158

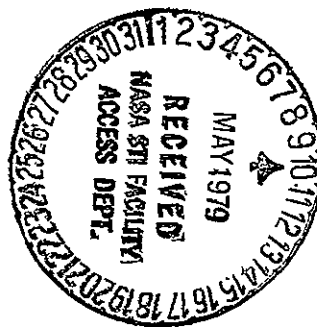
{NASA-CR-160158} ENVIRONMENTAL PERFORMANCE
EVALUATION OF AN ADVANCED-DESIGN SOLID-STATE
TELEVISION CAMERA Final Report {Fairchild
Imaging Systems) 123 p HC A06/MF A01

N79-21249

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FINAL REPORT
ENVIRONMENTAL PERFORMANCE EVALUATION
OF AN ADVANCED-DESIGN
SOLID-STATE TELEVISION CAMERA
February 1979



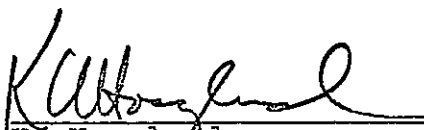
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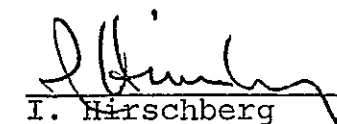
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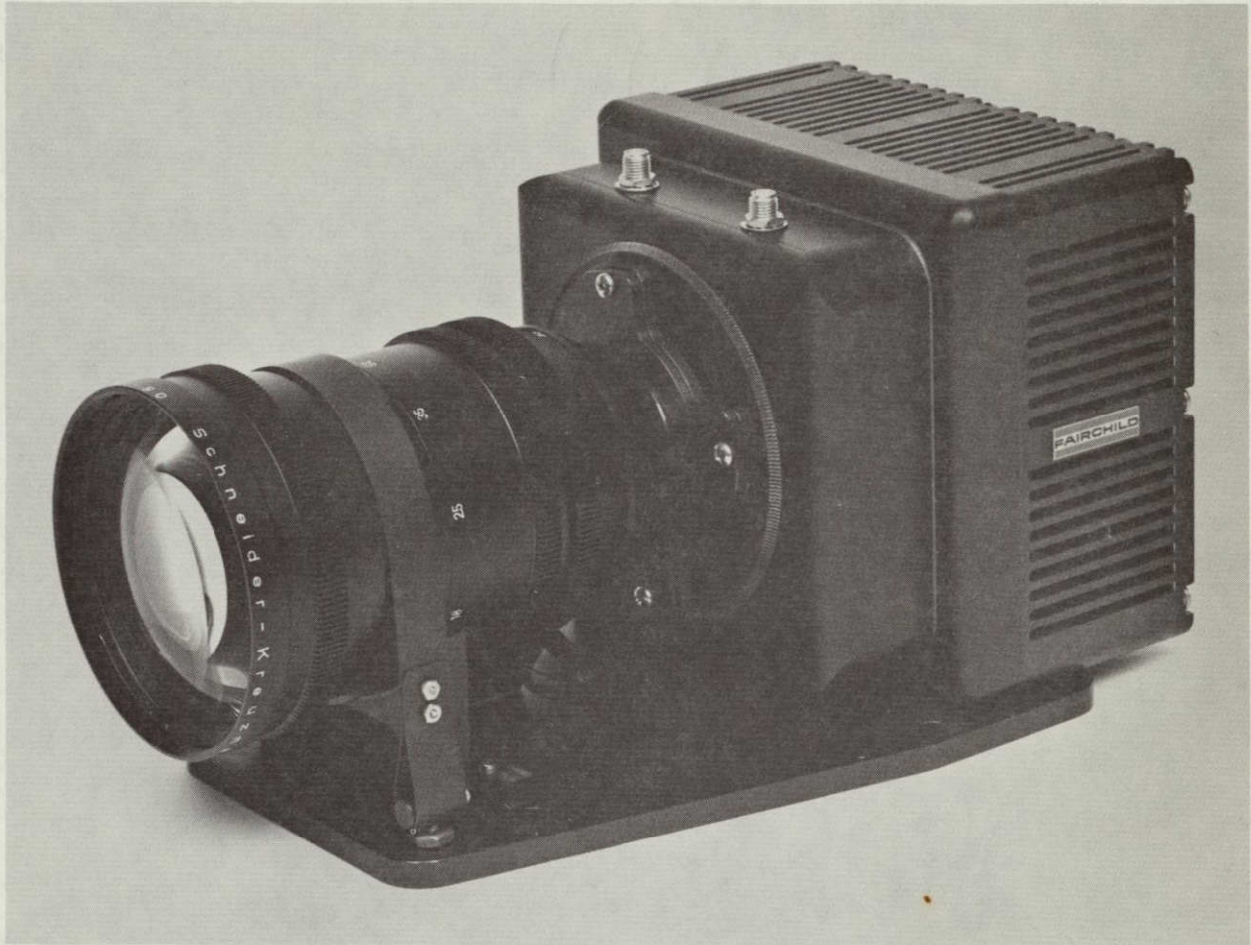

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ABSTRACT

The development of an advanced-design black-and-white solid-state television camera which can survive exposure to space environmental conditions was undertaken. A 380 x 488 element buried-channel CCD is utilized as the image sensor to ensure compatibility with 525-line transmission and display equipment. Specific camera design approaches selected for study and analysis included (a) component and circuit sensitivity to temperature (b) circuit board thermal and mechanical design and (c) CCD temperature control. Preferred approaches were determined and integrated into the final design for two deliverable solid-state TV cameras. One of these cameras was subjected to environmental tests to determine stress limits for exposure to vibration, shock, acceleration, and temperature-vacuum conditions. These tests indicate performance at the design goal limits can be achieved for most of the specified conditions.

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1.0 PURPOSE

1.1 OBJECTIVE

The objective of this Final Report is to describe the effort required to perform the engineering, design, development, fabrication, test, and delivery of two advanced-design black-and-white solid-state television cameras.

1.2 END PRODUCT

The end product of this contractual effort consists of two solid-state television cameras which utilize buried-channel CCD's (charge-coupled devices) as image sensors. These cameras employ a scanning technique which allows the CCD's to be used with conventional transmission characteristics and monitor displays meeting Electronic Industries Association (EIA) commercial standards.

Based on design investigations, several important features have been recommended and included in the end product design to make it compatible with the varied environmental requirements of advanced space programs. One of the two cameras was subjected to a range of vibration, shock, acceleration, and temperature-vacuum conditions to demonstrate the environmental stress-test limits of the camera design.

2.0

SCOPE

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Fairchild has provided the necessary resources to perform development and test of two advanced-design black-and-white solid-state television cameras using a buried-channel CCD as the image sensor.

The buried-channel interline-transfer CCD image sensors are particularly useful for solid-state TV cameras where small size, low power operation, high sensitivity and extreme ruggedness are necessary characteristics for operation in a space environment. The CCD (380 x 488 elements) insures full compatibility with 525-line television transmission and display monitors without requiring the use of pseudo-resolution or special formatting techniques. Additional features incorporated into the camera design to meet specific aspects of the NASA/JSC requirement include:

- Electrical and mechanical design for camera operation at -65°F to at least +200°F, corresponding to the operating range rating of available MIL spec components.
- Mechanical design which enables the cameras to withstand vibration, shock and acceleration such as encountered during a space mission.
- A thermoelectric temperature control feature for the CCD which minimizes thermally generated dark current defects and reduces the average dark-signal level thereby effecting an increase in useful sensitivity and dynamic range.
- Utilization of ALC/AGC techniques capable of accomodating a scene illumination range of $10^6/1$.

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- CCD clocking options which enable all sensor elements to be read out in either 1/60 or 1/30 second while maintaining full compatibility with 525-line television system specifications.

The specific design requirements and the design implementations are discussed in detail in paragraph 3.2 of Section 3. The end product prototype camera development is described in paragraph 3.3 and the acceptance test procedures and results are presented in Section 4 and Appendices A and B. Conclusions and recommendations concerning the camera environmental performance evaluation are included in Section 6.

3.0 TECHNICAL REQUIREMENTS

This section presents a technical synopsis of program results for each of the tasks defined by Section 3.0 requirements of the contract Statement of Work. Major subsection headings conform with the Statement of Work subsection nomenclature.

3.1 GENERAL

3.1.1 Study Requirements

Study tasks were selected to develop alternate approaches and concepts applicable to SOW objectives. These were then examined in detail, including breadboard tests where necessary, to determine preferred approaches and concepts to be implemented in the deliverable solid state cameras. Study task results are summarized in the Component and Circuit Sensitivity to Temperature, Circuit Board Thermal and Mechanical Design, and CCD Temperature Control subsections which follow:

A. Component and Circuit Sensitivity to Temperature

During the design phase of the program, extensive testing was performed to determine the effect of high and low temperatures on camera performance. The breadboard camera circuitry was placed in an environmental chamber and the camera's video output was monitored at various temperatures. As the temperature of the test chamber was lowered, undesirable effects such as horizontal video smearing were observed. Modifications made to the circuitry to cure such problems included adjusting resistance values, changing resistors from carbon-type to metal-film type and adding components in key places in the video board circuitry. To improve camera high-temperature performance, similar changes were

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made. These changes were not as extensive since the changes made to improve performance at low temperatures also helped the camera to perform well at high temperatures. The additional changes included the addition of buffering circuitry on the logic board.

B. Circuit Board Thermal and Mechanical Design

Since the cameras are required to operate in a vacuum ambient, special attention was given to eliminate heat build-up on the circuit boards. The breadboards were probed for hot spots and the components in these areas were noted. When the printed circuit cards were manufactured, the areas on the cards where these components would be located were provided with a layer of copper. This layer of copper extended to a side of the printed-circuit card and terminated in a strip of copper along the edge. The printed circuit boards were fastened to the camera case along this edge, thus conducting the heat away from the components through the copper strips to the camera case. Clamping the circuit boards to the camera case in this fashion also helped to eliminate flexing of the boards. A conformal coating meeting NASA/JSC requirements for outgassing was also applied to the boards to add mechanical strength and reduce the board's susceptibility to moisture.

C. CCD Temperature Control

Temperature control of the CCD is necessary to minimize the buildup of dark charge which doubles for each 8 to 10°C increment above 25°C. It is also desirable to limit extreme low temperature excursions of the CCD to minimize detuning due to temperature dependent effects on optimum bias and gate drive electrode potentials.

The approach selected for temperature control implementation is shown in Figure 3-1. This circuit operates in conjunction with the thermistor located in CCD-TE module previously developed for the prototype SSTV camera. Under synchronization control signals from the logic circuitry, the circuit will determine whether the CCD needs to be cooled or heated to maintain an optimum operating temperature. In either case, the thermoelectric device will be energized or de-energized only during the vertical blanking interval. This feature minimizes video glitches due to switching transients. If cooling is required, the output driver supplies a normal polarity signal to the thermoelectric device. Heating is obtained by reversing the drive signal polarity.

An important advantage of the temperature controller is its power efficiency. No thermoelectric power is consumed unless the ambient temperature is higher or lower than the desired range. Typical operating characteristics for this circuit and a 380 x 488 element CCD are shown in Figure 3-2.

3.1.2 Design Requirements

The results of the study effort, trade-off analyses, and breadboard tests were integrated into a design for the deliverable cameras. The camera circuitry is shown in block diagram form in Figure 3-3. The finalized circuit diagrams for the deliverable cameras are presented in paragraph 3.3 of this Section. Nearly all of these circuits are contained on three printed circuit boards: (1) The Logic/Driver Board (2) The Video Processor Board, and (3) The ATC-ALC/Array Board.

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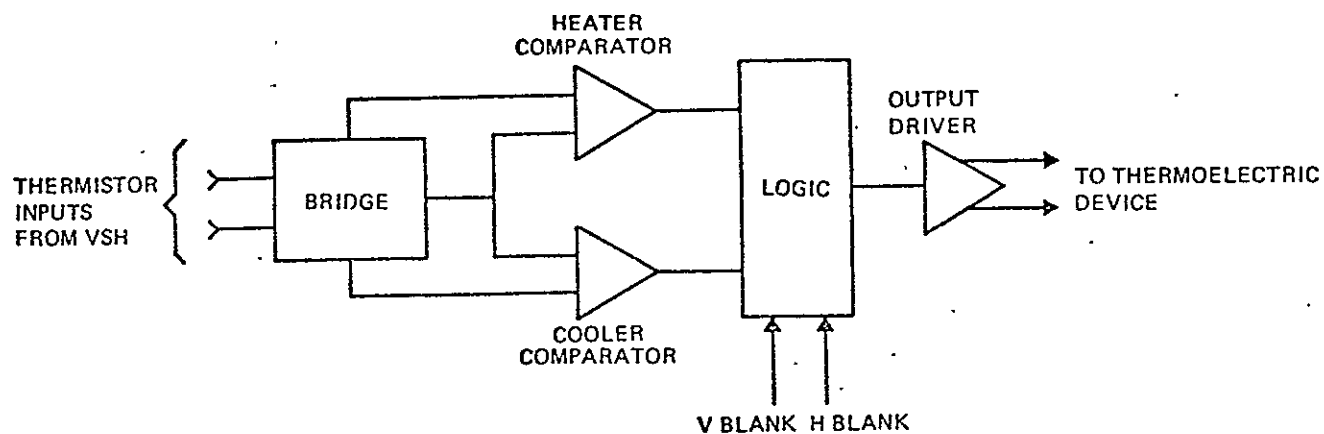


FIGURE 3-1 TEMPERATURE CONTROLLER BLOCK DIAGRAM

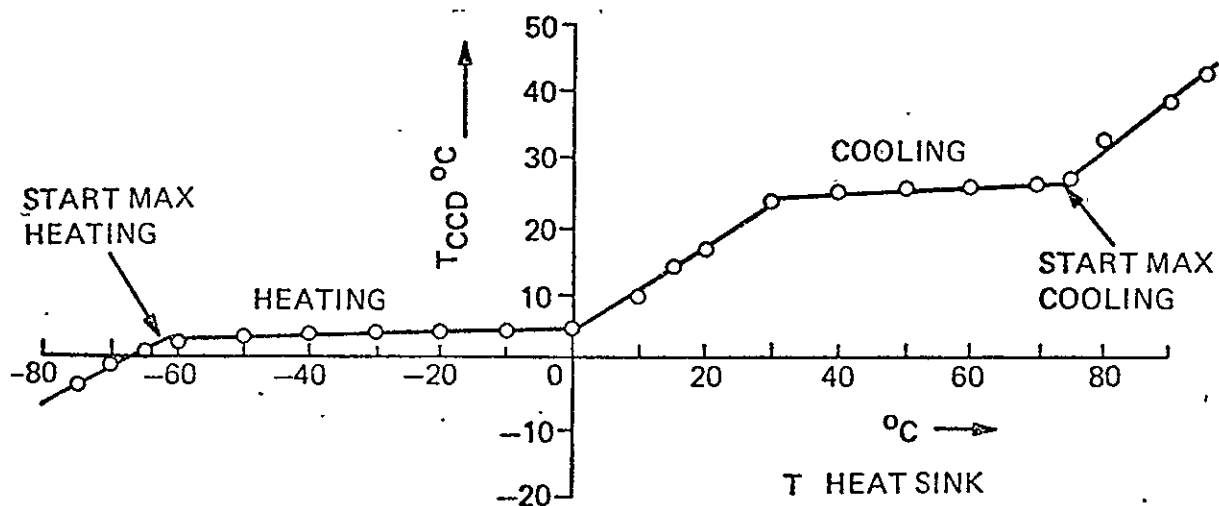


FIGURE 3-2 TEMPERATURE CONTROLLER CHARACTERISTIC CURVE

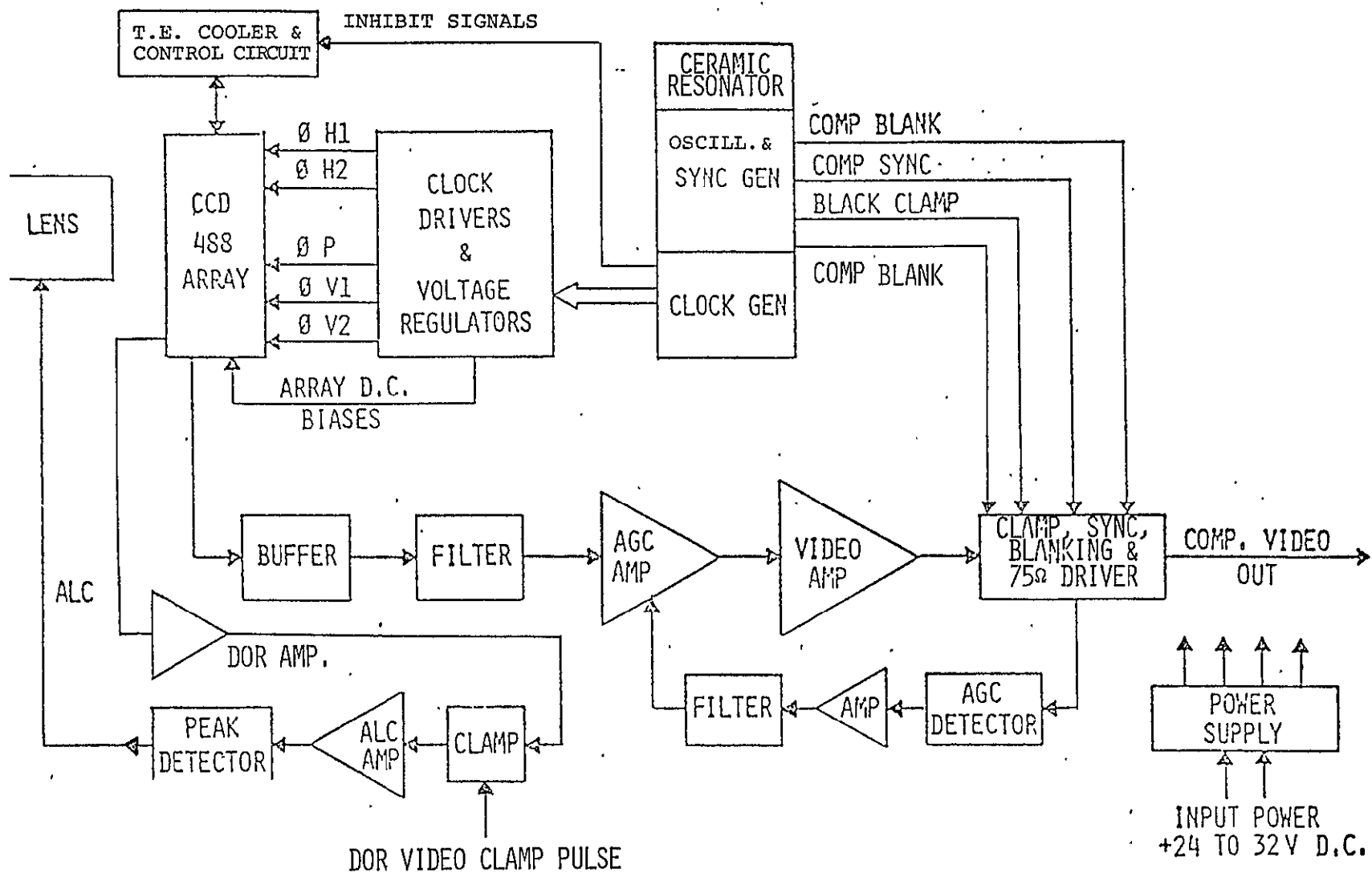


FIGURE 3-3 ADVANCED DESIGN SSTV CAMERA BLOCK DIAGRAM ...

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The first board (see Figure 3-4) generates all TV sync, drive and blanking signals in accordance with EIA-RS-170. An RCA TA6993W LSI-TV sync chip, in combination with a 504KHz resonator, is used to generate these TV timing signals. Additional counters, gates, flip-flop and buffers are used to generate the timing logic signals for the CCD array. The array logic driver stages, voltage regulators and setup pots for the array are also located on this board. FSDS hybrid drivers are used to drive the array.

The second circuit board (see Figure 3-5) contains all of the video circuits, which consists of: an input buffer; a Nyquist filter; a variable gain AGC stage; a fixed gain video amplifier and video processor stages, which perform black-level clamping, pedestal adjustment, and blanking insertion. In addition, there is an AGC detector, filter and amplifier stage and the ALC circuits to control the auto-iris lens. There is provision for operating with either manual video gain or with AGC.

The third board (see Figure 3-6) contains the ALC servo circuit and the ATC (Automatic-Temperature-Control) circuit.

A short summary of specifications for the deliverable cameras is given in Table 3-1.

3.2 DESIGN SPECIFICATIONS

Table 3-2 summarizes the detailed performance specifications applicable to the deliverable solid state camera. These specifications are in conformance with the requirements of the contract Statement of Work for all paragraphs 3.2.1 through 3.2.17, inclusive. The requirements and the implementations are discussed in detail in the following paragraphs 3.2.1 through 3.2.17.

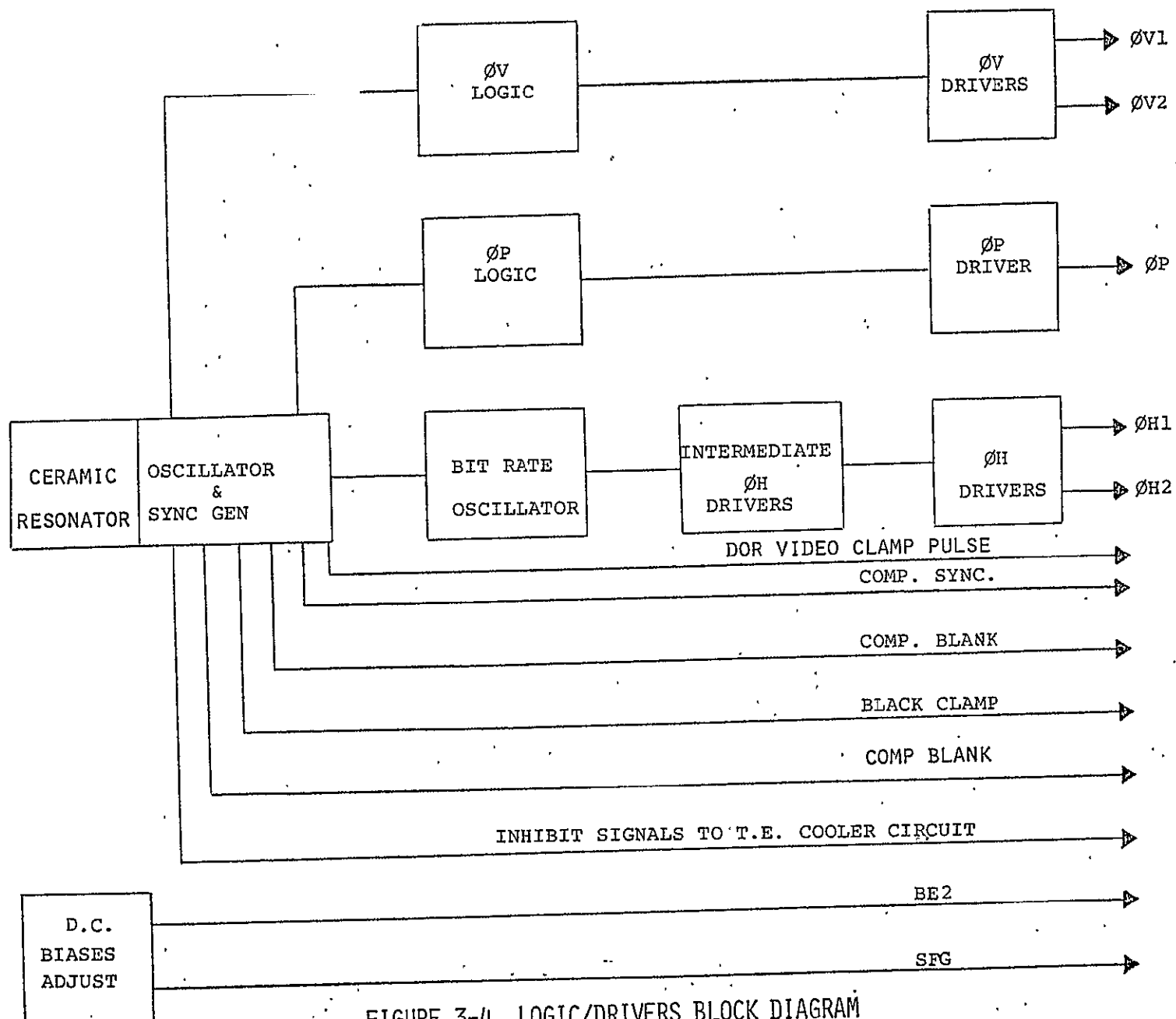


FIGURE 3-4. LOGIC/DRIVERS BLOCK DIAGRAM

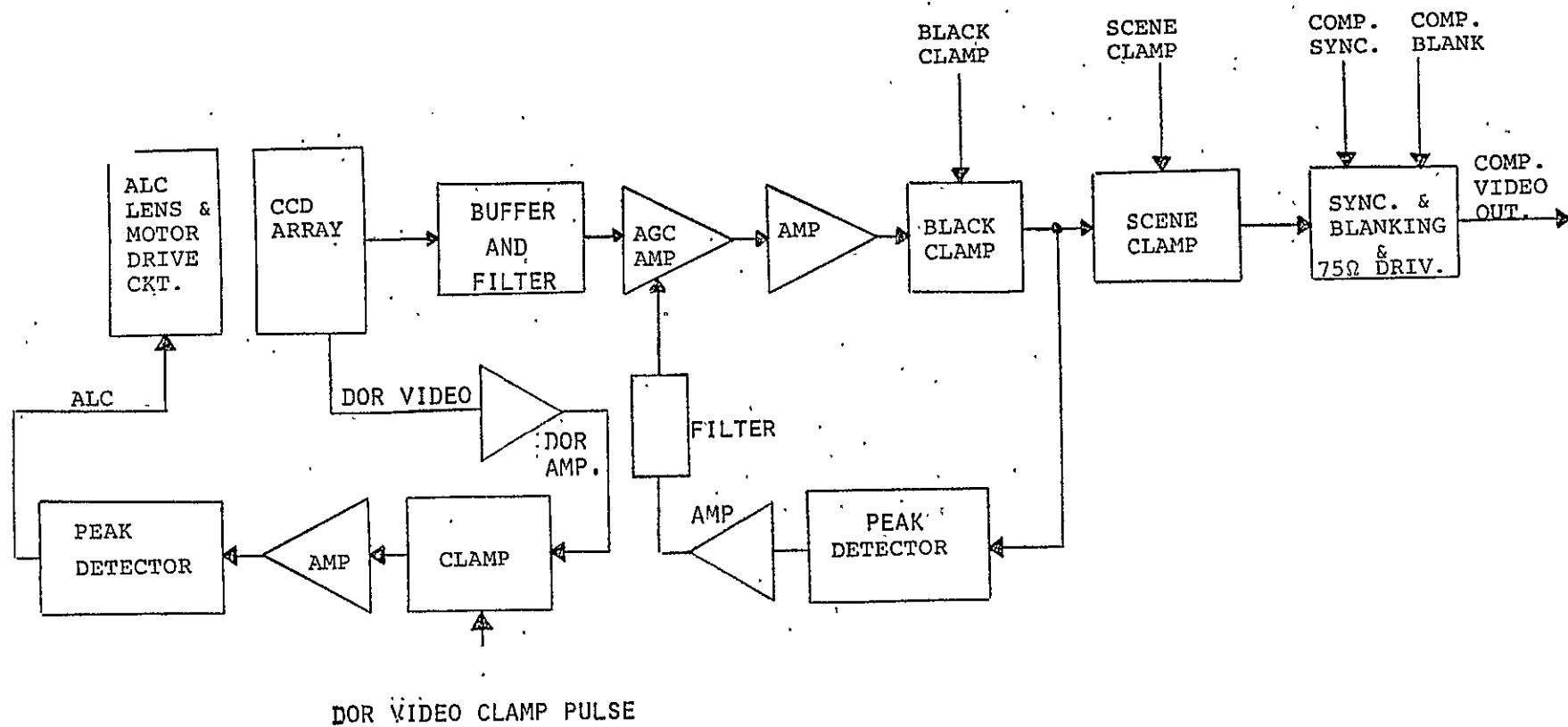


FIGURE 3-5 . VIDEO PROCESSOR BLOCK DIAGRAM

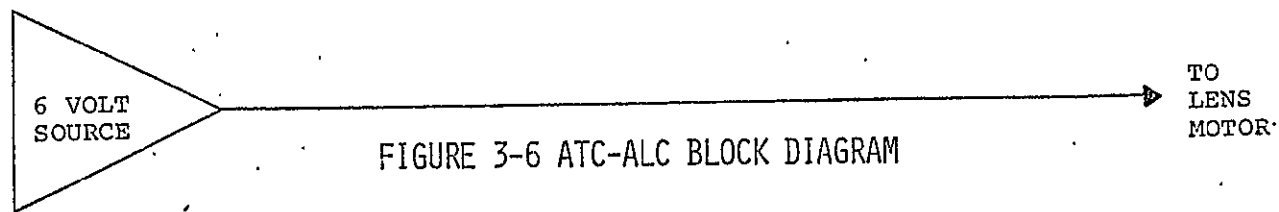
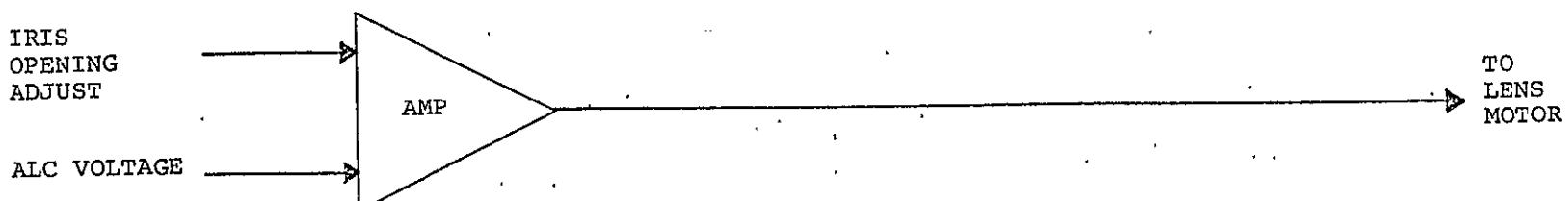
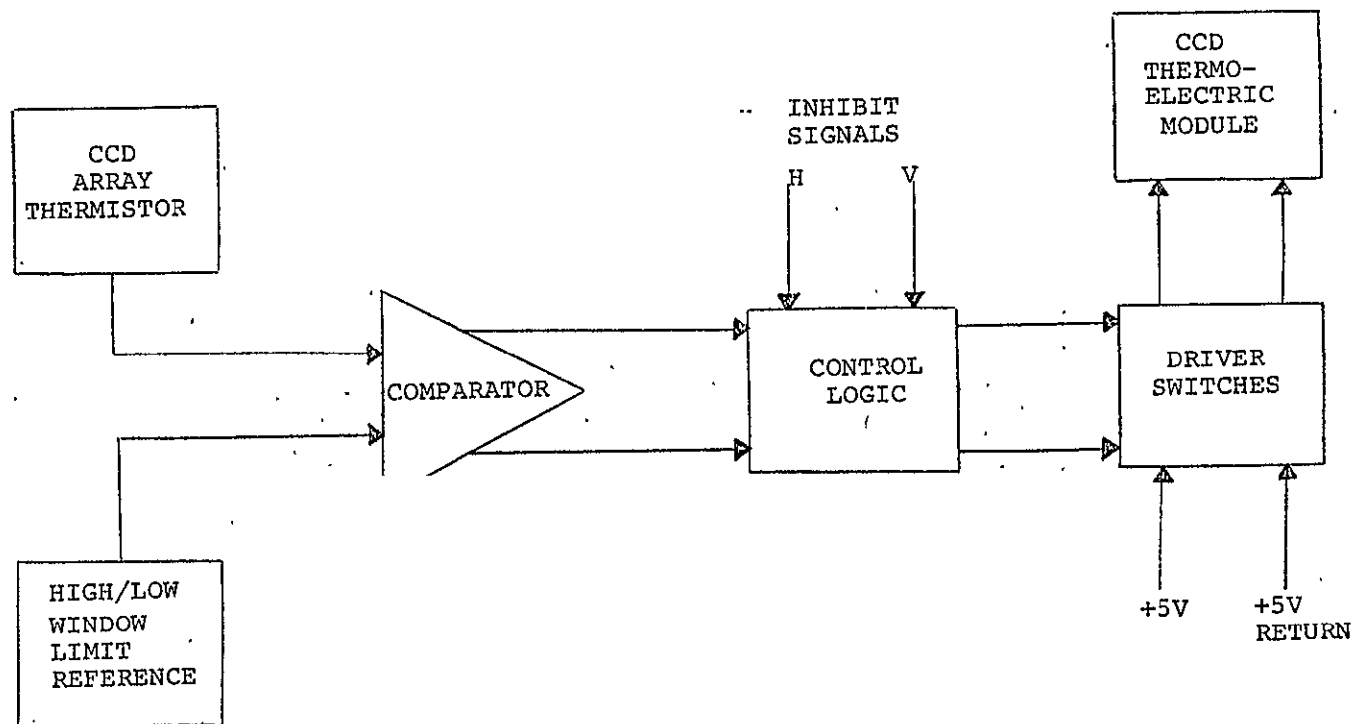


FIGURE 3-6 ATC-ALC BLOCK DIAGRAM

TABLE 3-1

SPECIFICATIONS

CCAID-488 ADVANCED DESIGN SSTV CAMERA

Sensor	Fairchild CCD 488 x 380 array
Spectral Response	0.45 to 1.1 Micrometer
Optics	Auto-Iris f/2-f/360, "C"-Mount
Sensitivity (Note 1)	Sensor Illuminance 5×10^{-2} fc for 40 db SNR
ALC/AGC Range	10^6 Scene Luminance Range
Geometric Linearity	No Camera Distortion. System Performance limited by lens and display.
Frame Rate	30 Frames/sec.
Line Rate	15,750 Lines/sec. (nominal)
Format	488 lines: 380 picture elements/line
Sync	2:1 standard interlace
Video Output	1V p-p, composite video (RS 170)
Video Line Output	500 ft., 75 ohm
Power (uncooled)	5 watts (Note 2)
Camera Size	(see drawing, Figure 3-7)
Weight (including zoom lens)	3.7kg.
Operating Temperature	-50°C to +95°C at Camera Case

NOTES:

1. Highlight illumination with 2854°K source (tungsten) for a S/N ratio of 100/1 (peak signal to temporal RMS noise ratio).
2. The camera will operate at this power from ± 12 VDC and +5 VDC supplies. DC to DC converters are supplied for operation from an unregulated +28 VDC supply.

TABLE 3-2

DETAILED CAMERA PERFORMANCE SPECIFICATIONS

		<u>SOW-Paragraph No.</u>
RESOLUTION, TVL PH		
High resolution mode	285x485 (HXV)	3.2.1,3.2.9
FIELD/FRAME INTERLACE RATIO	2 to 1	3.2.2
FORMAT ASPECT RATIO,HXV	4 x 3	3.2.3
VERTICAL SCAN		3.2.4
Frame rate	60/sec	
Field rate	30/sec	
Line periods/frame	525	
GRAY SCALE STEPS ($\sqrt{2}$)	10	3.2.5.1
DYNAMIC LIGHT RANGE (with ALC)	1000:1 min.	3.2.5.2
OPERATING VOLTAGE	+28V $\pm$ 4VDC;	3.2.6,3.2.7
AND POWER	25W max.	
OUTPUT VIDEO FORMAT		3.2.8
Load Impedance	75 Ω $\pm$ 5%	3.2.8.1
Composite video polarity	Black negative	3.2.8.2.1
Signal levels, IRE units		3.2.8.2.2
reference white	+100	
blanking level	0	
sync	-40	
peak-to-peak	140	
Composite output video		
voltage	1V p-p (nom.)	3.2.10
Blanked picture signal, with		
setup	0.714 $\pm$ 0.1V	3.2.10.1
Sync signal (from OVDC,ref.)	0.286 $\pm$ 0.05V	3.2.10.2
Setup, blanking level to		
reference black level,		
(IRE units)	7.5 $\pm$ 5	3.2.10.3

TABLE 3-2 (Continued)

		Ref. Exhibit "A" SOW Paragraph No.
SIGNAL-TO-NOISE RATIO	40db (min	3.2.11
GEOMETRIC DISTORTION(exc.lens)	<2%	3.2.12
SPOTS AND BLEMISHES	(see below)	3.2.13
Dark Current Non-Uniformity		
Responsivity Non-Uniformity		
BLOOMING	ALC/AGC inhibited	3.2.14
CAMERA OPTICS	Schneider-Variogon 1:2.0/18-90mm.	3.2.15
CAMERA CONTROLS	ALC Adjust Auto/Man.Video Gain	3.2.16
CAMERA INTERFACES		
Connectors	Output Video	
	Camera Power	
	Gen Lock In.	3.2.17
SPOTS AND BLEMISHES		3.2.13

A spot or blemish shall be defined as a video signal transition equal to or greater than 7% of the CCD sensor saturation signal observed with the sensor uniformly illuminated at a level corresponding to 50% saturation. The size of a spot or blemish shall be determined by counting the number of scan lines on which the transition occurs; i.e., the number of lines per frame on which the transition is greater than 7% of saturation signal. The total number of white and dark spots shall be less than or equal to:

- 10 spots over 1 but less than or equal to 4 TV lines/frame
- 2 spots over 4 but less than or equal to 8 TV lines/frame
- 0 spots over 8 TV lines/frame

No horizontal black lines resulting from a failed CCD element shall be allowed. The number and length of vertical black lines resulting from a failed CCD element shall be less than or equal to:

TABLE 3-2 (Continued)

- 4 lines within the full (unblanked) imaging area
- 1 line or portion thereof within the central area of 190 (H) x 244 (V) CCD elements.
- 0 lines over 1/4 picture height length within the central area of 293 (H) x 488 (V) CCD elements.

The dark current non-uniformity shall not be greater than 10 IRE units across the active area of the image sensor when the channel gains are adjusted to provide a full scale output (100 IRE units) for a high light scene illumination of 1 fl.

The non-uniformity in responsivity shall not be more than 15 IRE units across the active area of the image sensor when the sensor is uniformly illuminated to the point just below saturation.

3.2.1 Resolution

Requirement: The buried-channel CCD matrix shall be no smaller than 488 (V) x 380 (H) elements. The number of vertical scan lines shall be compatible with the EIA positive interlace format.

Implementation: The camera design uses the Fairchild CCD2120, a buried-channel area imaging sensor with 488 x 380 picture elements. The interline-transfer organization of this device provides interlaced video. The device is operated with a TV sync generator to assure compatibility with EIA standard television format.

3.2.2 Interlace Ratio

Requirement: Positive 2 to 1.

Implementation: The CCD2120 was specifically designed for a positive 2 to 1 interlaced readout. The normal operating mode is to alternate between transferring video information from odd and even numbered lines to the shift registers thus providing alternating odd and even fields.

3.2.3 Aspect Ratio

Requirement: The aspect ratio shall be 4 horizontally by 3 vertically.

Implementation: The format of the CCD2120 has been designed to provide a nominal 4 x 3 aspect ratio. The image sensing sites are located on 30 uM horizontal centers and 18 uM vertical centers. The dimensions of the image sensing area are 11.40 mm horizontally by 8.78 mm vertically.

3.2.4 Vertical Scan

Requirement: Nominal 60 fields/second, 30 frames/second and 525 lines/frame.

Implementation: The CCD2120 with its 488 active lines has been designed to be fully compatible with 525 lines/frame EIA standard video. The camera design uses an integrated circuit television sync generator controlled by a ceramic resonator to accurately generate the timing for 60 field-30 frame operation.

3.2.5 Operating Light Ranges

3.2.5.1 Gray Scale Response

Requirement: Under normal conditions with a 10 step logarithmic gray scale target (contrast ratio 32:1) projected onto sensor faceplate with highlight illumination of 5×10^{-2} foot-candles, the camera shall resolve the 10 steps with its output displayed on a television monitor and exhibit a noise ratio of 40dB minimum (refer to 3.2.11).

Implementation: The highlight illumination and contrast ratio specified are within the linear output range of the CCD2120 array. The video amplifier has an adequate linear range to reproduce the signal. The typical saturation exposure of the array is $0.2 \text{ uJ/cm} = .004 \text{ fcs}$. In normal operation, the integration time is $1/30$ second thus the saturation exposure corresponds to an illumination of 12×10^{-2} foot-candle. The specified illumination level is then 41.67% of typical saturation illumination. Considering the 32:1 contrast ratio the last step is then $1/77$ of saturation illumination. The array has a typical dynamic range of 300:1 thus the design readily accommodates the 10 gray scale requirement

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3.2.5.2 Dynamic Light Range

Requirement: The camera shall meet performance specifications over a minimum 1000:1 scene highlight illumination range. Minimum high-light illumination is 5×10^{-2} foot-candles on the sensor faceplate, corresponding to 1 foot-lambert minimum scene illuminance.

Implementation: The camera uses a combination of automatic light control (ALC) and automatic gain control (AGC) to maximize the dynamic range. The ALC controls the illumination reaching the sensor. It is implemented with a spot-filter Auto Iris lens. This lens uses non-AGC'd video as the feedback to an iris control servo. The iris' range is from a relative aperture of f2 to f360 and can thus accommodate an illuminance ratio of 32000:1.

3.2.6 Operating Voltage

Requirement: Nominal 28 Volts. Camera shall operate normally from 24 to 32 volts. Camera circuits shall be isolated so that power line and other circuit noise does not feed through to the video output.

Implementation: A power supply unit is used with the camera. This unit operates from 28 ± 4 volts and provides the DC voltages required by the camera. Two DC-DC converters are provided. The first produces + 12 volts and - 12 volts for the analog circuits and the logic/driver circuits. The second converter generates the 5 volts for the thermo-electric cooler and cooler control circuitry. Decoupling is provided at critical circuits, such as the array, to prevent noise from coupling through to the output video.

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3.2.7 Power Consumption

Requirement: The design of this camera shall be such that power consumption shall be minimized.

Implementation: The unconditioned minimum camera power consumption is 5 watts, as measured at the ± 12 volt and +5 volt supply lines with the TE cooler and lens drive motor off. Assuming a worst case DC-DC converter efficiency of 32%, the corresponding 28VDC power drain is 16 watts, which increases to 25 watts maximum with the TE cooler on.

3.2.8 Output Video Format

3.2.8.1 Standard Load Impedance

Requirement: Output impedance 75 ohms. Load impedance 75 ohms.

Implementation: The 75 ohm output impedance is obtained with an emitter follower output which will drive a 75 ohm load.

3.2.8.2 Composite Picture Signal

3.2.8.2.1 Polarity

Requirement: The standard polarity of the output of the camera shall be black-negative.

Implementation: The camera has been designed to provide standard black-negative polarity video output.

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3.2.8.2.2 Signal Levels

Requirements: The composite picture signal shall be measured using both IRE units and volts. Measurement of signal levels shall be made in accordance with appropriate portions of 58 IRE 23.51 IRE Standards on Television measurement of Luminance Signal Levels.

Implementation: These measurement requirements have been reflected in the Acceptance Test Procedure.

3.2.8.3 Sync Signal Waveforms

Requirement: The sync signal waveform shall meet EIA Standard RS-170. The internal sync generator shall have the capability of locking to an external EIA composite sync signal.

Implementation: The camera design uses an RCA type TA6993W integrated circuit TV sync generator. The composite blanking and the composite sync signals from this IC are combined with the video at the appropriate voltage levels to produce the composite picture signal. When the sync generator is controlled by a ceramic resonator it provides sync timing to RS-170. The internal camera sync generator will lock to an external EIA composite sync signal with a peak-to-peak amplitude of 0.286V.

3.2.9 Output Resolution Response

Requirement: Resolution response shall be measured in accordance with IEEE 208, 60 IRE 23.52, Standard on Video Techniques: Measurement of Resolution of Camera Systems. The horizontal resolution response shall not be degraded by the video processing. The limiting resolution shall be no less than 70% of the number of TV elements.

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Implementation: The Acceptance Test Procedure reflects the above referenced specification. Two separate tests are involved. In the first, limiting resolution is determined. The vertical resolution shall exceed $0.7 \times 488 = 342$ TV lines/picture height. The horizontal resolution shall exceed $0.7 \times 0.75 (380) = 200$ TV lines/picture height. The limiting resolution is determined using a standard test chart with graduated wedges. The resolution response is measured using a spatial frequency test chart with test bars at $1/8$, $1/4$, $1/2$ and Nyquist-limit horizontal resolution.

The camera has been designed for limiting resolution of:

Horizontal: 285 TV lines/picture height
Vertical: 485 TV lines/picture height.

These resolutions are for the normal operating mode with $1/30$ second integration time. An alternate operating mode providing $1/60$ second integration time is also incorporated into the camera design. It reduces the vertical resolution to about $2/3$ of the normal Nyquist limit value and has no effect on the horizontal resolution. Thus in the alternate readout mode the camera's vertical resolution is specified as 325 TV lines/picture height.

3.2.10 Output Video Voltage

Requirement: The composite picture signal amplitude from sync tip to reference white, when the camera drives a 75 ohm load, shall nominally be 1 volt peak-to-peak.

3.2.10.1

The blanked picture signal with setup, as measured from blanking level to reference white level, shall be 0.714 ± 0.1 volts (100 IRE units).

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3.2.10.2

The synchronizing signal, as measured from 0 volts DC shall be $+0.286 \pm 0.05$ volts (40 IRE units).

3.2.10.3

The standard setup shall be 7.5 ± 5 IRE units measured from blanking level to reference black level.

Implementation: The camera has been designed to provide the video voltage levels cited above. Factory adjustments are incorporated into the camera design so that the various voltages can be set during initial testing.

3.2.11 Signal-To-Noise Ratio

Requirement: The S/N for nominal camera operation shall be 40dB minimum, peak-to-peak noncomposite picture signal voltage to rms random noise voltage within a 4.2 MHz bandwidth. The S/N for impulse or interference noise sources shall be 40dB minimum.

Implementation: The camera has been designed with noise minimization as an important guideline. This has been reflected in particular attention to decoupling and isolation of ground paths. For the purposes of the S/N measurement in the Acceptance Test Procedure, the rms noise will be considered as 1/6 of the measured peak-to-peak noise.

3.2.12 Geometric Distortion

Requirement: The TV camera geometric distortion exclusive of the lens shall not exceed a displacement of any picture element from its true position in the object being viewed by more than $\pm 1\%$ of

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the picture height within Zones 1 and 2 and $\pm 2\%$ of the picture height within Zone 3. For any increment of 5% of the picture height, the rate of change of displacement of any picture element shall not be greater than 0.5% of the picture height. Zone 1 shall be defined as the area within an inscribed circle centered within the scanned area the diameter of which is one-half the picture height. Zone 2 shall be the area included within an inscribed circle centered within the scanned area with diameter equal to the picture height, but excluding the area of Zone 1. Zone 3 shall be the remaining area of the scanned picture outside of or excluding Zones 1 and 2.

Implementation: Since the CCD array is a semiconductor device manufactured with high precision mask making techniques, the geometric spec cited above is easily met.

3.2.13 Spots and Blemishes

Requirement: The total number of white and dark spots equal to or greater than 7% of saturation shall be less than or equal to:

- 10 spots over 1 but less than or equal to 4 TV lines/frame
- 2 spots over 4 but less than or equal to 8 TV lines/frame
- 0 spots over 8 TV lines/frame

No horizontal black lines resulting from a failed CCD element shall be allowed. The number and length of vertical black lines resulting from a failed CCD element shall be less than or equal to:

- 4 lines within the full (unblanked) imaging area
- 1 line or portion thereof within the central area of 190 (H) x 244 (V) CCD elements
- 0 lines over 1/4 picture height length within the central area of 293 (H) x 488 (V) CCD elements.

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The dark current non-uniformity shall not be greater than 10 IRE units across the active area of the image sensor when the channel gains are adjusted to provide a full scale output (100 IRE units) for a highlight scene illumination of 1 fL.

The non-uniformity in responsivity shall not be more than 15 IRE units across the active area of the image sensor when the sensor is uniformly illuminated to the point just below saturation.

Implementation: The spot and blemish and non-uniformity requirements are met by inspecting the image obtained from available array with these requirements in mind. An array with the appropriate characteristics is then selected. Array temperature control using the thermoelectric cooler also helps reduce spots and blemishes since it has been established that both dark signal and blemishes can be significantly reduced by cooling.

3.2.14 Blooming

Requirement: The solid-state image sensor is particularly susceptible to "blooming" - the spreading of an optical overload-generated charge into adjacent regions. The Contractor shall propose various solutions to minimizing the blooming problem, incorporate the most acceptable solution into the camera, and include in the final report a detailed discussion of the solution proposed and further work that may be done in this area.

Implementation: An auto iris lens using an iris-spot filter for wide range ($10^4/1$) light control in combination with automatic video amplifier gain control (AGC) was selected as the most effective method for minimizing CCD sensor blooming.

3.2.15 Camera Optics

Requirement: The camera shall be equipped with a zoom lens with a minimum 5:1 zoom capability and with aperture and focus controls. The lens shall be an auto-iris spot-filter type with a minimum T-number commensurate with the best commercially available lenses. The iris shall have the capability of providing relative aperture from the fully open T-number through T-300.

The lens shall allow the camera, when operating observing a sunlit scene of 2 foot-candles, to meet all the requirements specified herei

The lens shall be mounted to the camera such that it will be interchangeable with other lenses. A C-mount interface shall be provided. The lens shall be considered a part of the camera for all specifications herein. No development is intended in the optics area.

Implementation: The camera design accommodates standard C-mount television lenses. The deliverable cameras are equipped with black-spot auto-iris Schneider Varigon type CP100 zoom lenses. The CP100 lens is a high-performance f/2 design with 18 to 90 mm focal length range. An f/2 lens with 80% optical transmission will provide 5×10^{-2} fc sensor highlights (which is a reference ATP test condition) with scene highlight luminance of one lumen/sq. ft. (1 fL). The spot-iris effective aperture control range of the CP100 extends from fully open (T2.2) to fully closed ($T \infty$).

3.2.16 Camera Controls

Requirement: The camera shall be equipped with external controls that are accessible to the operator. The controls shall be so located, positioned, and labeled with sufficient size and contrast to allow ease of reading and operation.

Implementation: See outline drawing (Figure 3-7)

3.2.17 Camera Interfaces

Requirement: The camera shall include two connections so as to facilitate the provision of camera power from one source and camera video to a standard commercial-type TV monitor. The contractor shall select the appropriate connectors to meet all the requirements of this specification. They shall be small with a minimum number of pins and have a positive locking mechanism. Pin assignments are to be determined by the contractor.

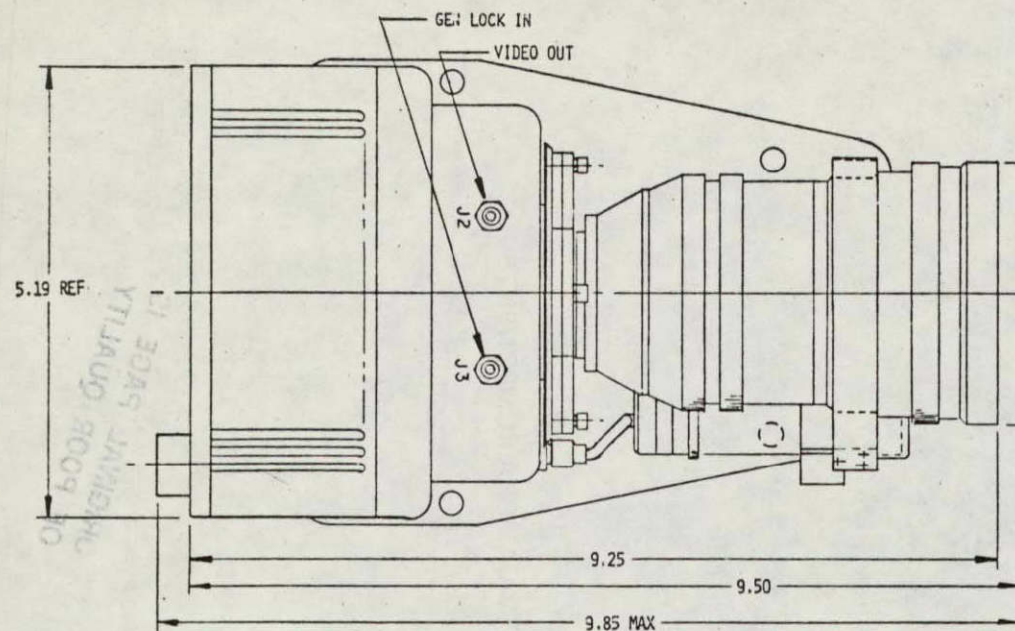
Implementation: The camera interface requirement is a power source of 24 to 32 volts D.C. to the camera power supply unit and a standard commercial-type TV monitor. The input power connects to a pair of pendant wires from the camera power supply unit. Video is fed to the display by coax cable which has a standard BNC connector.

3.3 CAMERA DEVELOPMENT

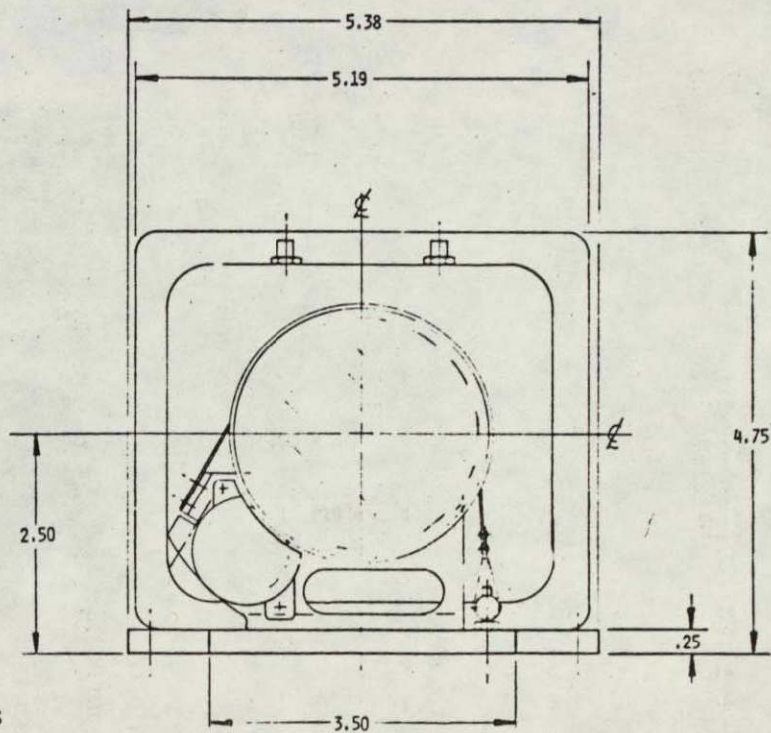
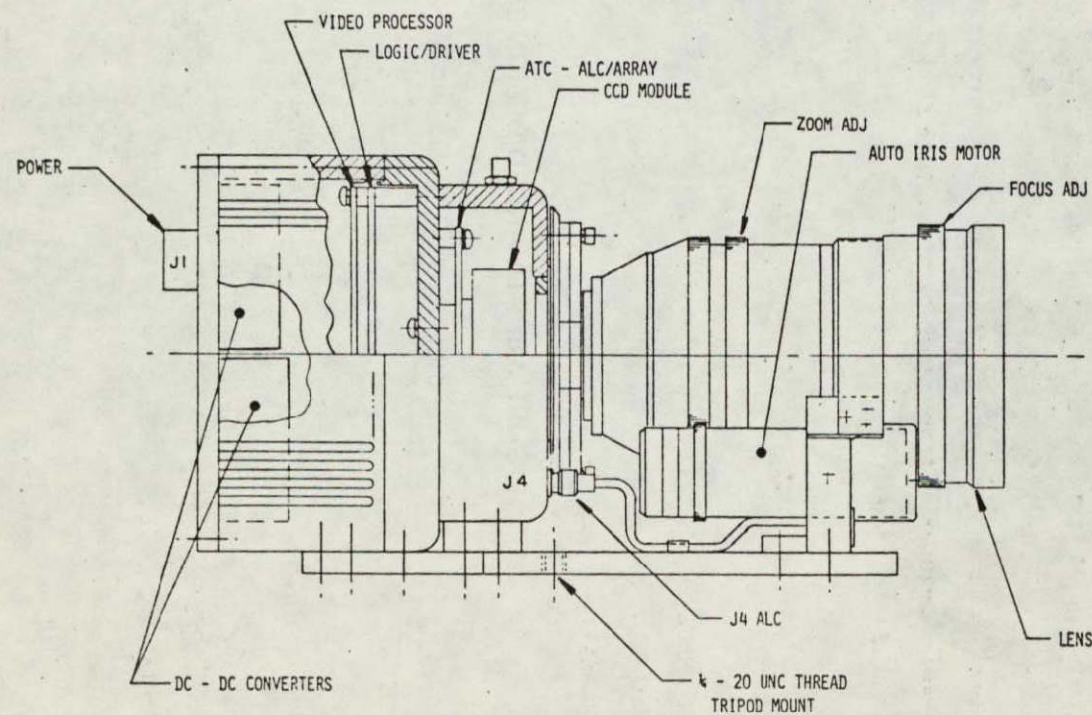
The advanced Design SSTV Camera contains five major electrical sub-assemblies as shown in figure 3-7 and partially shown in the exploded assembly view, Figure 3-8:

- CCD-TE Module
- ATC-ALC/Array Board
- Logic/Driver Board
- Video Processor Board
- Power Supply Assembly

Interconnections between the subassembly components are as illustrated in Figure 3-9.



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FIGURE 3-7 ADVANCED DESIGN SSTV CAMERA OUTLINE

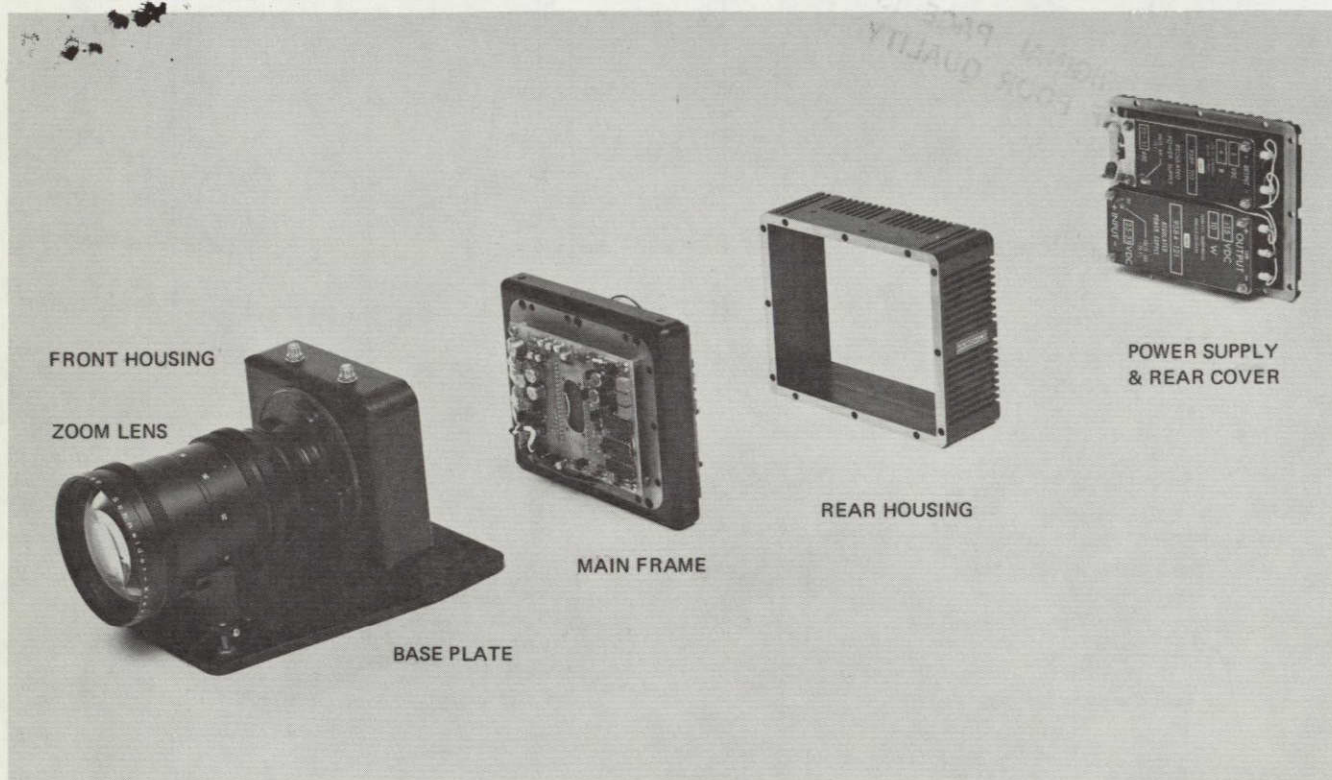
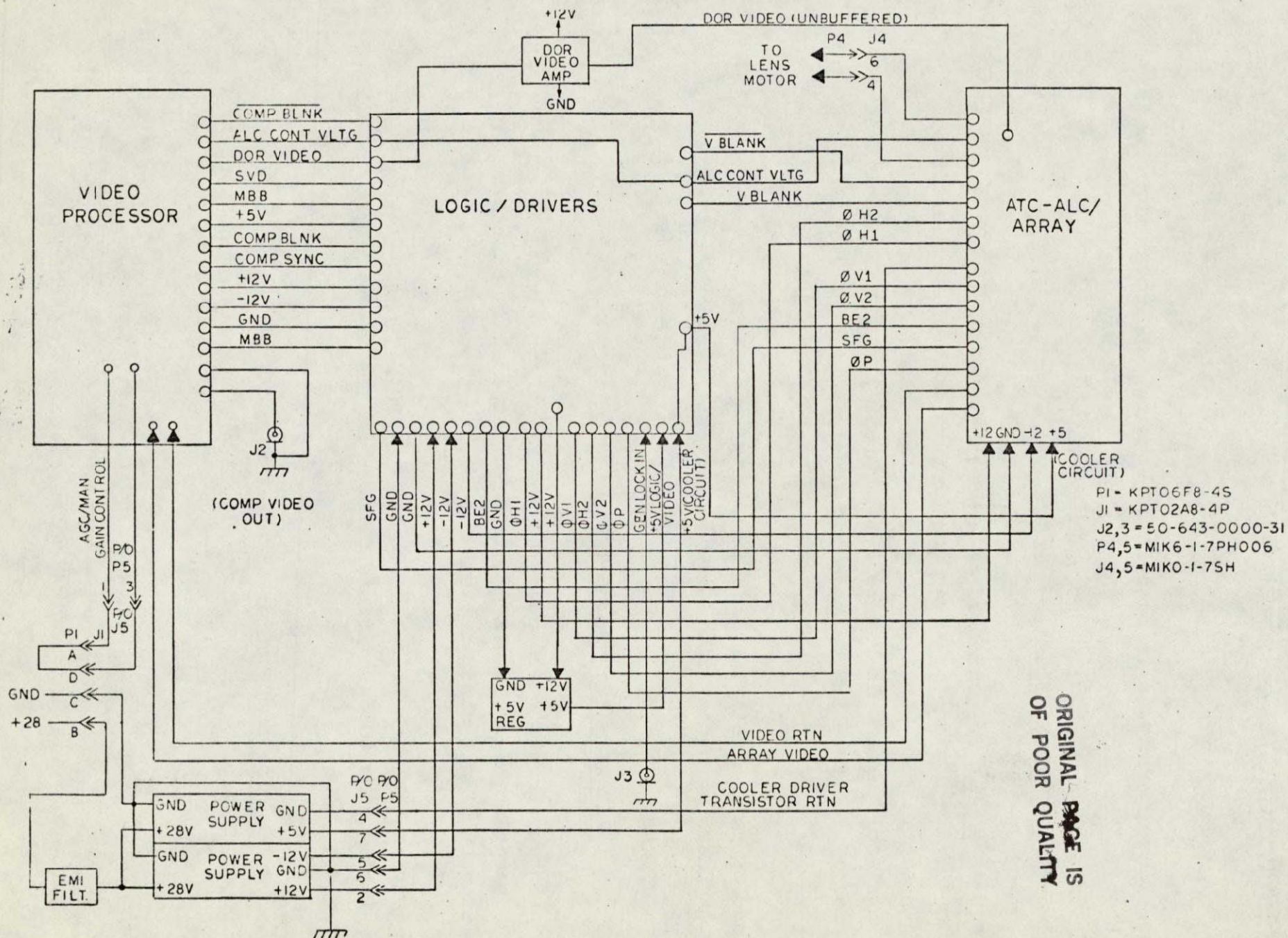


FIGURE 3-8. ADVANCED DESIGN SSTV CAMERA COMPONENTS

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FIGURE 3-9 INTERCONNECT DIAGRAM

A zoom lens assembly, plus baseplate, housing, and cover components, as shown in the frontispiece photograph, completes one system.

3.3.1 CCD-TE Module

The CCD-TE Module is comprised of a 488 x 380 element CCD array, a thermoelectric device for array temperature control, a thermistor, and a heat transfer block, all of which are contained within a hermetic enclosure as in Figure 3-10. A similar CCD-TE module was used for a prototype SSTV camera previously developed for NASA/JSC Contract No. NAS 9-14844 (Ref. Report No. ED-AX-76, Rev. 1, 4/77).

The enclosure contact pins interconnect with the ATC-ALC/array circuit board when the module is mounted on the camera main-frame member (see Figure 3-8).

3.3.2 ATC-ALC/Array Board (Figure 3-11)

This printed circuit board contains interface circuitry for CCD-TE array operation, including the automatic temperature control (ATC) and automatic light control (ALC) functions.

RC decoupling networks for the CCD array supply voltages are on this board in addition to an emitter-follower stage for buffering the CCD array video output.

A second major circuit function on the ATC-ALC/array board is the ALC circuit which accepts an ALC control voltage from the video processor board and develops an output for operating the lens iris-drive motor.

The remaining circuit is the ATC circuit which accepts an input from the CCD array thermistor to determine if cooling or heating is needed to maintain an optimum operating temperature. In either case, the

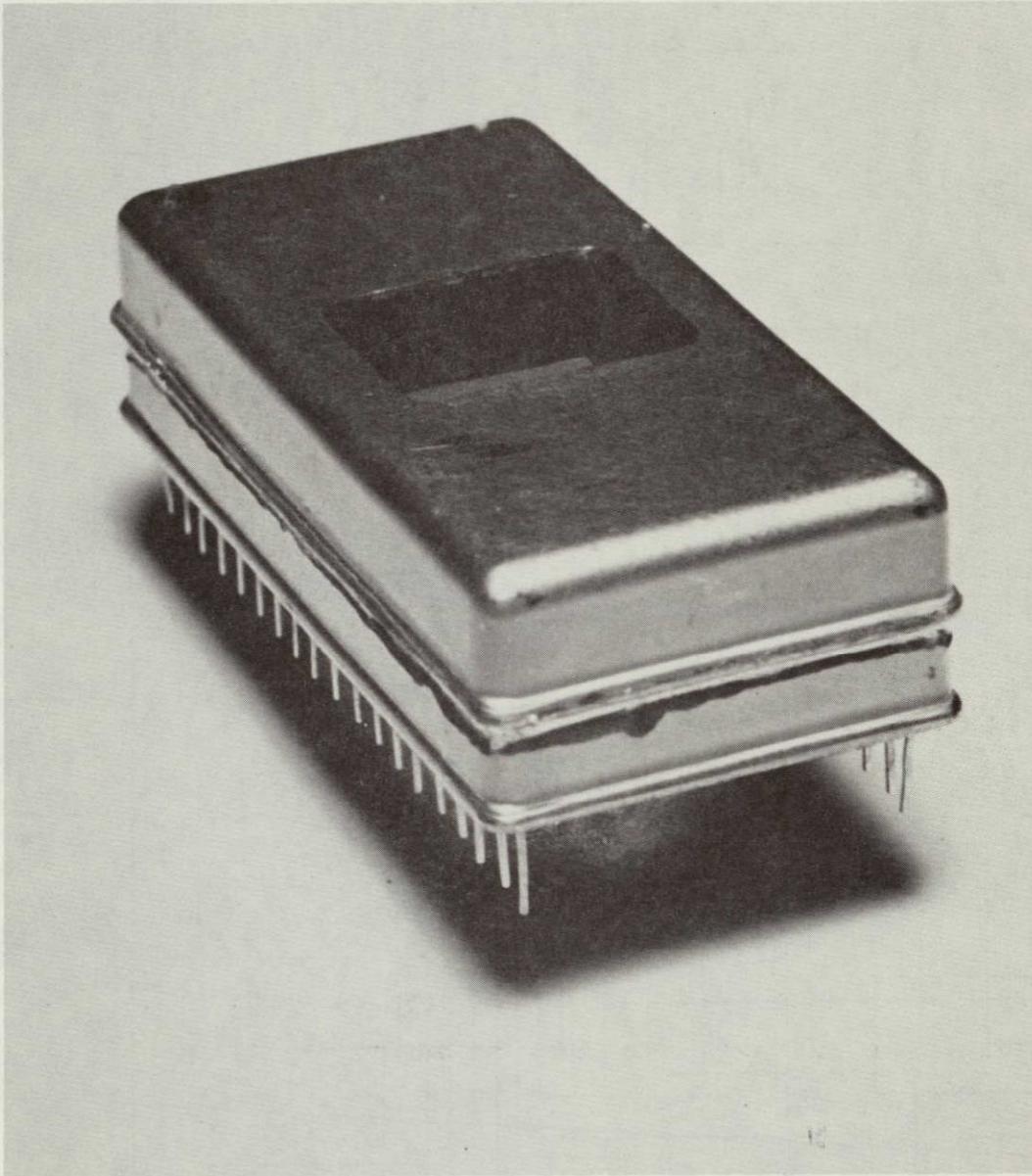


FIGURE 3-10. CCD-TE MODULE ENCLOSURE

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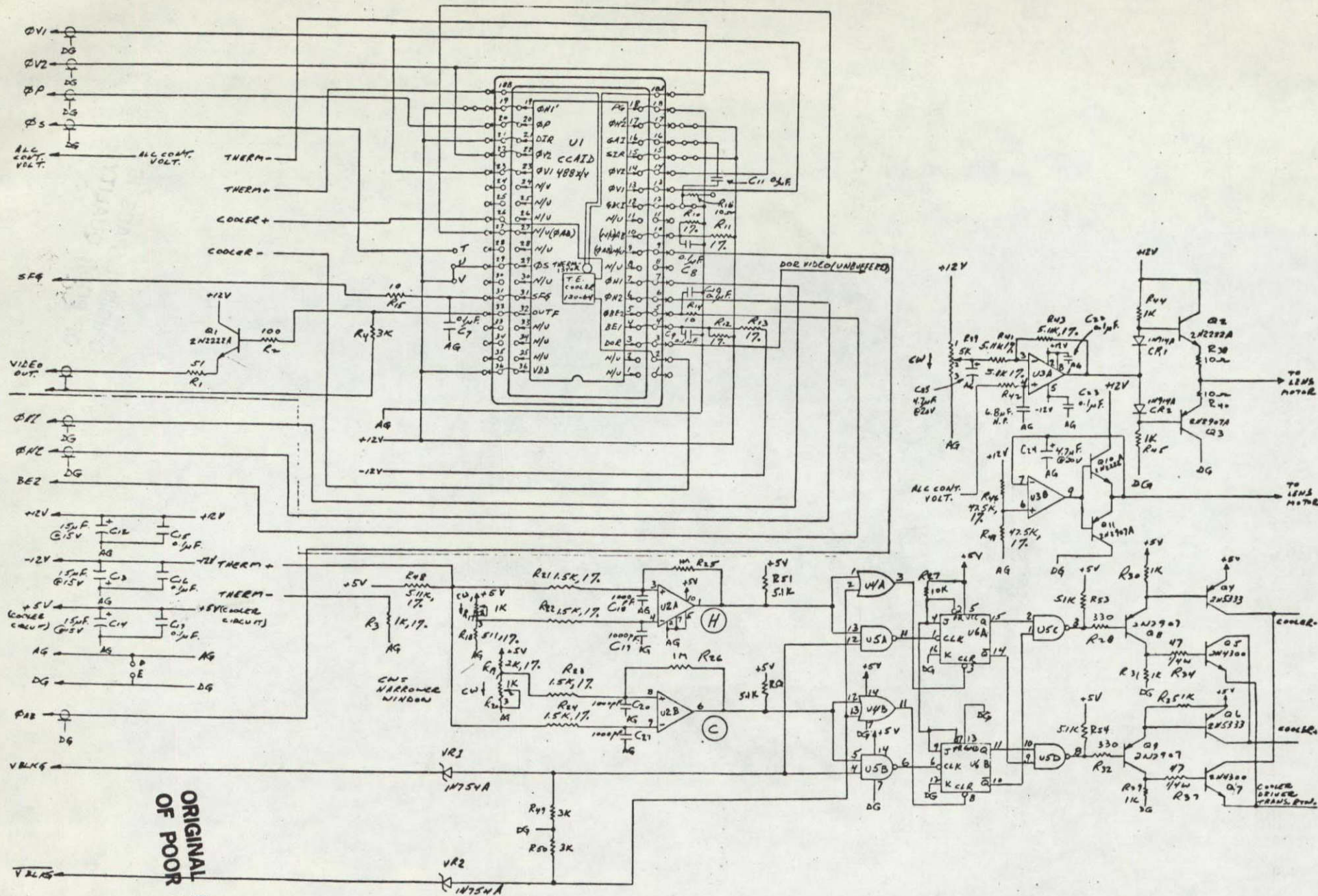


FIGURE 3-11 ATC-ALC/ARRAY BOARD

thermoelectric device is energized or switched off only during vertical blanking periods to eliminate switching glitches from the output video.

3.3.3 Logic/Driver Board (Figure 3-12)

The logic portion of the logic/driver board produces all the timing signals required for RS-170 operation in addition to the clocking signals necessary for operating the CCD. An LSI TV sync generator chip in conjunction with a ceramic resonator and additional logic circuitry (such as counters, gates, drivers, flip-flops) provide these signals. The driver portion consists of logic driver stages which are used to drive the capacitance of the CCD array electrodes. The regulator circuits on this board provide regulated and variable voltages to the driver stages so that the amplitudes and D.C. levels of the clock signals may be adjusted to the proper level for the CCD array.

3.3.4 Video Processor Board (Figure 3-13)

The video processor board contains circuitry which processes the CCD video signal and produces the RS-170 compatible output signal. Large signals excursions which occur during inactive video time are eliminated by an FET gate at the input of the video board. This is followed by a low-pass filter which attenuates the clock component of the video signal. The next stage is an AGC amplifier which is followed by a fixed-gain stage. The processor stages follow and consist of a driver black-clamp stage, a blanking adder, a gamma corrector, a sync adder and an output stage. A separate scene-clamp circuit and ALC circuit branch out of the video chain at appropriate points in the circuitry. The ALC circuit provides the drive signal to the circuitry on the ATC-ALC/array board by buffering, clamping, peak-detecting and amplifying a signal from the CCD array which is proportional to the light level incident on the CCD.

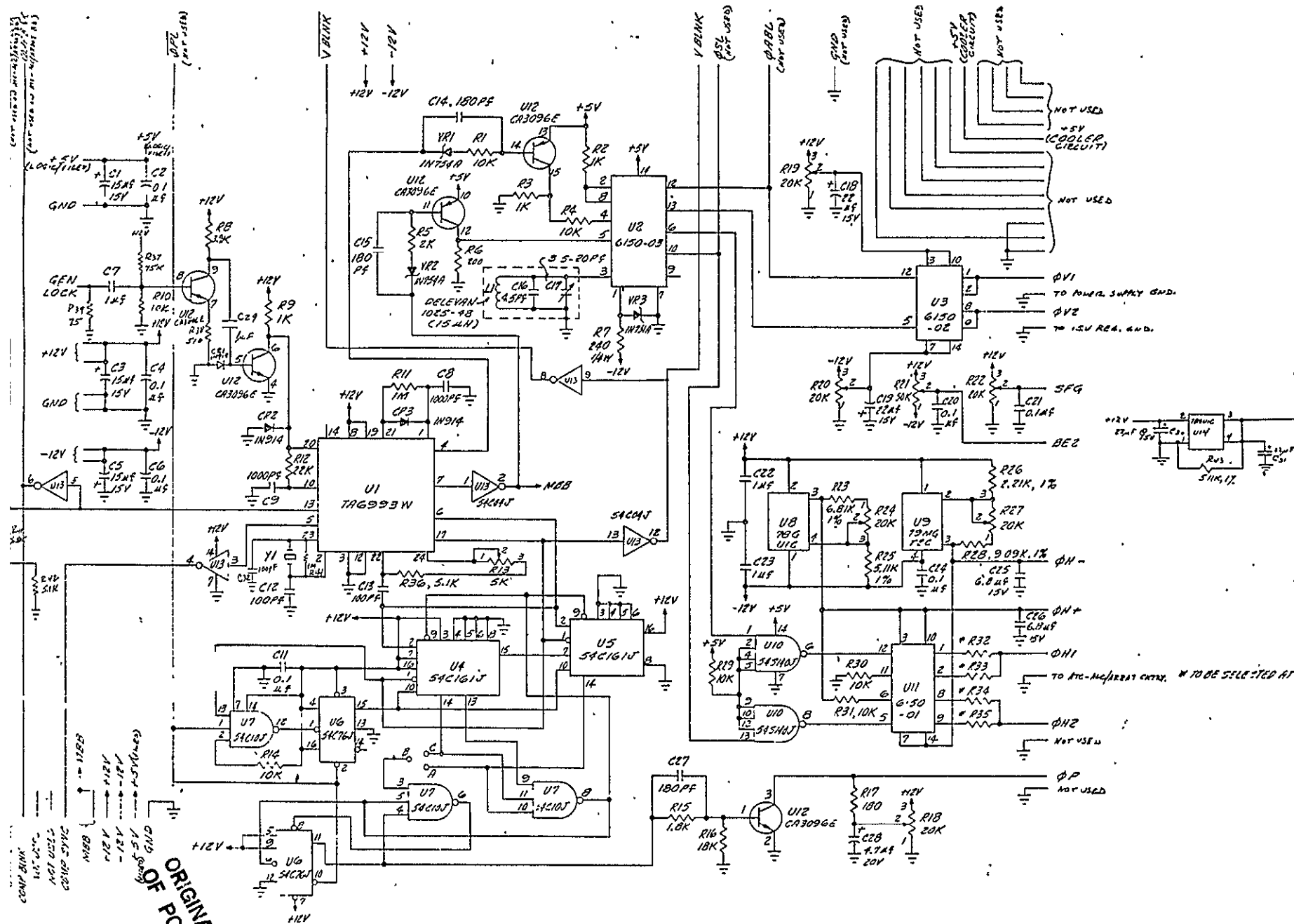


FIGURE 3-12 LOGIC/DRIVER BOARD

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The scene clamp circuit clamps the darkest information in a scene to an adjustable D.C. voltage resulting in contrast enhancement of low-contrast signals.

3.3.5 Power Supply Assembly

The power supply assembly converts 28 volts D.C. into three DC output voltages. These outputs are +12 volts at 300mA, -12 volts at 115 mA and +5 volts at 47 mA (720mA with cooler on). The supply will accept an input voltage range of 24-32 volts without any degradation of camera performance.

3.4 ENVIRONMENTAL REQUIREMENTS

The design goal environmental requirements and related camera design implementations are discussed in the following paragraphs 3.4.1 through 3.4.4. The zoom lens was selected with consideration of these design goal requirements, however this camera component was not subjected to environmental stress testing since the program scope did not include optics development.

3.4.1 Temperature

Requirement: The camera shall be designed to withstand the following:

- (a) Operating: +200°F to -200°F for a 2 hour period at each period at each extreme.
- (b) Non-operating: +200°F to -200°F for a six hour period at each extreme.
- (c) Pressure: Both conditions (a) and (b) above shall be at a pressure of 1×10^{-8} TORR.

Implementation: The camera design utilizes MIL spec. qualified passive and active circuit components wherever feasible. These components are typically rated for operation and storage temperature extending from an upper limit at or above 200°F to a lower limit of -67°F (-55°C). Also, the CCD is contained within a modular sub-

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assembly utilizing a thermoelectric device for maintaining the CCD array temperature within a preselected range much smaller than the camera temperature range. Supplemental camera heating is expected to be necessary for operation at temperatures below circuit component ratings, i.e., at temperatures in the range -67°F to -200°F .

3.4.2 Random Vibration (Non-Operating)

Requirement: The camera shall be designed to withstand an acceleration spectral density of:

20 to 70 Hz	Increasing, at 9db/octave, to $0.4\text{g}^2/\text{Hz}$ at 70 Hz.
70 to 500 Hz	Constant at $0.4\text{g}^2/\text{Hz}$.
500 to 2000 Hz	Decreasing, at 6db/octave, from $0.4\text{g}^2/\text{Hz}$ at 500Hz
Duration:	34 minutes per axis
Composite:	19.1 grms

3.4.3 Shock

The camera shall be designed to withstand a 20 g terminal sawtooth shock pulse of an 11 millisecond duration in each of three orthogonal axes (6 directions).

Implementation: (See paragraph 3.4.4)

3.4.4 Acceleration

The camera shall be designed to withstand a maximum plus or minus 5g's in each direction in each of the major axes.

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Implementation: Mechanical design features and components parts were selected to achieve or exceed the specified maximum levels for vibration (para 3.4.2), shock (paragraph 3.4.3) and acceleration (paragraph 3.4.4)

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4.0 ENVIRONMENTAL STRESS TESTS

Two advanced-design SSTV cameras were delivered in accordance with Contract SOW requirements. Before delivery, both cameras were subjected to an acceptance test (ATP) under standard laboratory conditions. Following this, one camera was set aside for delivery while the second camera was subjected to environmental stress testing. This section presents a technical synopsis of testing results, including early breadboard tests.

Details of the ATP and environmental stress test results will be found in the Appendices to this report. Appendix A describes the ATP and environmental test plan (QA Report No. 1615, Rev. B, November 1978), while Appendix B presents the report including the Acceptance and Environmental Test results. (QA Report No. 1651, 1/79)

4.1 BREADBOARD TEMPERATURE TESTS

Preliminary temperature testing of the camera circuitry was started in November 1977. During these tests the Logic/Drivers and the Video Processor breadboard circuits were checked and debugged to maximize the temperature range for satisfactory circuit operation; i.e., the range for maintaining acceptable composite video voltage levels without degradation of picture quality or resolution. Most of the circuit changes resulting from the temperature tests involved work on the video board. These changes were primarily necessary for proper operation at the lower end of the temperature range. They included adjusting resistor values, substituting 1% tolerance metal-film resistors to replace carbon types, adding a diode for temperature compensation and adjusting potentiometers to allow safety margins for timing changes due to temperature drift. The only change necessary on the logic/driver board consisted of re-routing a logic signal in order to partially unload a TTL output. The only change made for high temperature operation in-

volved adding a buffer circuit to the logic board. It was possible to effect this change in the final board design by re-routing logic signals.

4.2 VIBRATION TEST

After successfully completing the pre-delivery acceptance test, the deliverable camera that was selected for the environmental tests was subjected to the Vibration Test (see Appendix B, Section 2.0). The first axis was the vertical axis. Camera operation was checked on a video monitor before and after each axis in order to determine if the vibrations had any detrimental effects on the camera. The camera successfully completed the vertical axis test, but exhibited logic circuit problems after the lateral axis test. Upon inspection of the logic circuit and electrical tests, it was determined that the 504KHz crystal had failed. It was replaced with a more reliable ceramic resonator. Connections to the filter capacitors on the DC to DC converters broke during this test; the capacitors were replaced and conformally coated with improved support to sustain vibration. The camera was finally vibrated in the longitudinal axis. Operation of the camera after this test proved unsatisfactory due to problems on the video board - five capacitors had broken loose and one was chipped. They were replaced and the component side of the circuit board was inspected and recoated in order to eliminate this problem.

4.3 SHOCK TEST

The camera successfully completed the Shock Test at the specified maximum levels. (see Appendix B, Section 3.0)

4.4 ACCELERATION TEST

The camera successfully completed the Acceleration Test at the specified maximum levels. (see Appendix B, Section 4.0)

4.5 TEMPERATURE TEST

The Automatic Temperature Control circuit was adjusted to maintain the CCD array within a temperature range of +3°C to -20°C (37°F to 4°F). These limits were found by operating the camera in an environmental chamber prior to the temperature test. A capacitor on the video board was changed at this time to help eliminate any array black clamp problems. This change had no effect on other camera parameters.

The camera was first checked at the high end of the temperature range. Camera operation at the high end was successful until the 131°F step was reached. When the camera power was turned on at this point, the average temperature of the camera rose to 155°F. The vertical resolution had degraded enough to cause a temporary cessation of testing. In order to remedy the problem, two potentiometers on the logic board were replaced with lower resistance units to minimize the sensitivity to change in vertical clock voltages with temperature. Following this change the test was resumed and satisfactory camera operation was achieved with camera case temperatures as high as 215°F. Testing was stopped at this temperature to avoid melting solders used for assembly of the thermoelectric cooler.

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Low temperature-vacuum testing was completed by the early part of November. Satisfactory operation was achieved with camera case temperatures of -65°F which is near the low limit rating of MIL-spec components used in the camera. Below -70°F the camera operated with degraded image quality, with loss of video occurring at about -90°F . When the camera was turned on at this temperature there was no video except for a pattern consisting of vertical noise. After approximately one minute of operation, the power supply current began to cycle indicating that the CCD array heating was cycling on and off but the video had not changed. This demonstrated that the problem was not related to the CCD array. Video was restored after four minutes of operation, apparently as a result of self-heating effects. When the camera was brought to -115°F , ten minutes of self-heating was sufficient to restore the video signal to the same quality as previously observed at -90°F threshold. Testing was stopped at this point and the camera allowed to warm-up gradually while in the vacuum ambient.

4.6 ALC VOLTAGE VARIATIONS

The principal reason for including a measurement of ALC voltage during the environmental testing was to determine if the camera circuitry had been affected by these tests. Before and after these tests, the camera was checked for proper operation by observing that the camera would produce an acceptable image on the monitor. Such an image would verify that most of the camera circuitry was operating properly. Checking the ALC voltage for variations was done to verify that the rest of the camera circuitry, i.e., the ALC circuitry, was also working correctly. Since the ALC voltage is related to CCD performance, checking the ALC voltage for no before/after variation is also an indication that the CCD array performance did not change as a result of the test. When the ATP was prepared, it was erroneously assumed that the before/after ALC

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voltage change should not exceed 5%, based on the assumption of constant CCD array temperature conditions. As explained below, the actual ALC voltage changes were as great as 2/1 since the array TE cooler was cycling on at room temperature.

The ALC voltage is a function of the signal appearing at pin 3 (DOR) of the CCD array. This signal is proportional to the amount of light falling on the CCD array and to the amount of "dark current" produced by the CCD array. Due to thermal effects, the dark current is not zero and varies by a factor of about 2/1 for every 18°F change in temperature. Thus an 18°F temperature change in the CCD array temperature can cause the ALC voltage to change by a factor of two if no light is incident on the CCD. This is the explanation for the greater than 5% variation in the ALC voltage observed during the environmental testing when the light path was blocked by the lens mass model. When the ALC voltage was measured during the shock test, the camera was turned on only long enough (≈ 5 sec) to obtain an ALC voltage reading. This was done to minimize the effects of the cooler on the array dark current which would affect the ALC voltage. The voltage varied from 1.12 to 1.21 during the phases of the shock test. This variation was greater than 5%, but since the cooler can cause the array temperature to change from room temperature to 0°F in a matter of seconds, it is reasonable to expect that simply switching the camera on long enough to obtain an ALC voltage reading could easily account for the observed variation.

This is also the reason for the variation in ALC voltage reading before and after the acceleration test. The ALC voltage before the test was 1.21 volts and the ALC voltage after the test was 2.4 volts. The reading of 1.21 volts was taken at the end of the post-shock performance test while 2.4 volts was obtained at the end of the post-acceleration performance test. Since each performance was approx-

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imately 1/2 hour long, one might expect the array temperature at the end of each test to be about the same which would make the ALC voltage about the same. The voltages, however, varied by a factor of two. Since the temperature at the array can be as low as 80°F below room temperature, it is not surprising to expect that this temperature may vary as much as 18°F during a performance test. This would cause the factor of two changes in the ALC voltage above.

The 5% tolerance in ALC voltage was a reasonable choice when the ATP was written since it was assumed that the cooler would not be operating at room temperature. With the cooler off, temperature variations at the array would be small enough to keep the ALC voltage variations within 5%. Finally, once the ALC lens is connected to the circuitry, any variations in ALC voltage due to array temperature, etc. would not be a problem since the ALC feedback loop is closed and the circuitry would correct for any variations in light level or array temperature which affects array dark current output.

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5.0 RELIABILITY AND QUALITY EFFORT

The advanced design SSTV camera design evolved by expanding and supplementing a technology base established as a result of both previous and on-going Fairchild CCD-TV camera programs, including the following:

<u>Program (Contract No.)</u>	<u>Relation to SSTV Program</u>
NASA/JSC Prototype SSTV (NAS 9-14844)	Performance goals, exclusive of environmental tests and zoom optics, demonstrated.
Army Artillery TV (DAAD-05-74-C-0732 DAAA-21-75-C-0279)	Shell-launch environmental capability, including 14,000G shock, demonstrated.
USAF Electronic Gunsight TV (F-33615-76-C-1326)	Environmental capability in high performance aircraft demonstrated, including operation in 180°F ambient (with CCD cooling) in a series of F4-C Air Force flight tests.
Navy Missile Guidance (N00010-75-C-0289) (N60530-77-C-0106)	High-ΔT CCD-thermoelectric cooler development for 210°F ambient operation.

Since reliability predictions, including the analysis of failure modes and the effects on system performance, were in process for CCD-TV camera systems with features similar to the Advanced Design SSTV, it was possible to utilize these related program inputs during the study and trade-off analysis phase. Thus, no significant costs were incurred for additional reliability and quality assurance effort.

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In view of similarities in each camera system, a detailed reliability/quality program can be recommended as a follow-on effort based on a reliability analysis made for the USAF Cockpit Television Sensor (CTVS-formerly known Electronic Gunsight TV). The results of reliability and maintainability analysis for the CTVS System are contained in Fairchild Report No. ED-AJ-278, Rev. B, entitled Reliability and Maintainability Allocations, Assessments and Analysis Report, November 22, 1978, prepared for the AFSC Aeronautical Systems Division, Wright Patterson Air Force Base, Ohio 45433. The calculated MTBF for the CTVS system, as described in this report, is 3,713 hours.

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6.0

CONCLUSIONS AND RECOMMENDATIONS

Performance of the Fairchild Advanced Design SSTV cameras demonstrated that most of the design goal objectives for operation during and after exposure to extreme environmental conditions can be achieved. Although some circuit parts broke loose during the vibration tests, these failures were due to correctible defects in small parts attachment which were not found and corrected prior to test. Except for a quartz crystal oscillator, no failures of critical components such as the CCD sensor/TE cooler package or other major structural parts of the camera occurred. The oscillator crystal (which failed during the second-axis vibration) was replaced with a more rugged ceramic resonator. After repair and reinspection, the camera subsequently survived worst case shock and acceleration testing with no further problems.

The temperature-vacuum results support the conclusion that supplemental heating will be necessary for reliable operation with camera temperatures below -70°F . Although a lower limit without heating may be feasible, the additional effort required should include an extensive program of parts qualification testing (with component redesign, if necessary) to address the problem of reliable component operation at temperatures below existing MIL-spec rated values.

Performance at the high temperature limit of $+200^{\circ}\text{F}$ was shown to be feasible. However, adequate heat sinking is required to minimize case temperature rise due to self-heating effects. The implementation of image sensor temperature control, as described in paragraph 3.1.1, provides a means for maintaining the CCD array within a temperature range much smaller than the case temperature range. The power required for CCD cooling and heating could be significantly reduced by using very small CCD substrate packages with surface area not much greater than the silicon chip size.

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APPENDIX A

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SECTION I

ACCEPTANCE TEST PROCEDURE

1.0 SCOPE

The purpose of this Acceptance Test Procedure (ATP) is to demonstrate that equipment supplied by the Fairchild Imaging Systems Division (ISD) is suitable for use as a Solid State Television Camera System as defined by the requirements of Contract No. NAS9-15407.

2.0 TEST EQUIPMENT REQUIRED

The following test equipment will be used to verify the performance of the television camera system components:

- a) Fluke Digital Voltmeter, Model 8600A,
- b) CCD Resolution Test Target, 4 x 3 aspect ratio, TP#1
- c) Logarithmic Gray Scale Test Target, TP#2
- d) Spatial Frequency Test Target, TP#3
- e) Tektronix Light Meter, Model J6523
- f) Power Supply, D.C., Power Designs Model 3240, or equivalent
- g) Oscilloscope, Tektronix Model 7704A, or equivalent
- h) Neutral Density Filters, ND1.0, ND2.0 and ND3.0
- i) Tele-Measurement Light Box, Model TELE-PAT III
- j) Test lens, C-mount type, 25mm, f1.4 - f22
- k) Test Signal Generator, Tektronix Model 144
- l) Display Monitor, Conrac Model DZA14, or equivalent

The above test equipment will be suitably calibrated when necessary.
Check on data sheet.

3.0 VISUAL INSPECTION

Verify that the following equipment comprising the deliverable system is available. Record serial numbers on data sheet.

3.1 Solid State Television Camera Assembly

1 - Camera Electronics Unit

1 - Lens, Schneider Model VGN 2/18-90

4.0 TEST PROCEDURE

The following tests shall be performed while the television system is in a normal operation mode except where otherwise noted.

4.1 System Interconnection

See System Block Diagram, Figure 1.

4.2 Light Level Calibration

- a) Replace the Auto-Iris camera lens with the 25mm test lens.
- b) Adjust the voltage input to the light box to obtain approximately 500 f1 highlights with the test patterns in position.
Record reading on the data sheets.
- c. Place the ND2 filter in front of the test lens. Set the iris at f/4. Adjust camera alignment and lens focus until the test pattern image (TP#1) just fills the full width of the unblanked display raster. Adjust the lens iris to approximately one f stop below CCD saturation. Record f stop setting on the data sheets.
- d. Compute sensor highlight illumination I_H from the formula:

$$I_H = \frac{B \times 0.8}{4f^2 \times 100} \quad (fc)$$

where B is the TP highlight value, f is the f-stop value.

Record the computed I_H value for one-stop below saturation on the data sheet.

- e. Compute the f-stop value required to achieve $I_H = 5 \times 10^{-2} fc$ at the sensor faceplate with the ND2 filter in front of the lens. Adjust "B" value of light box if necessary. Record the

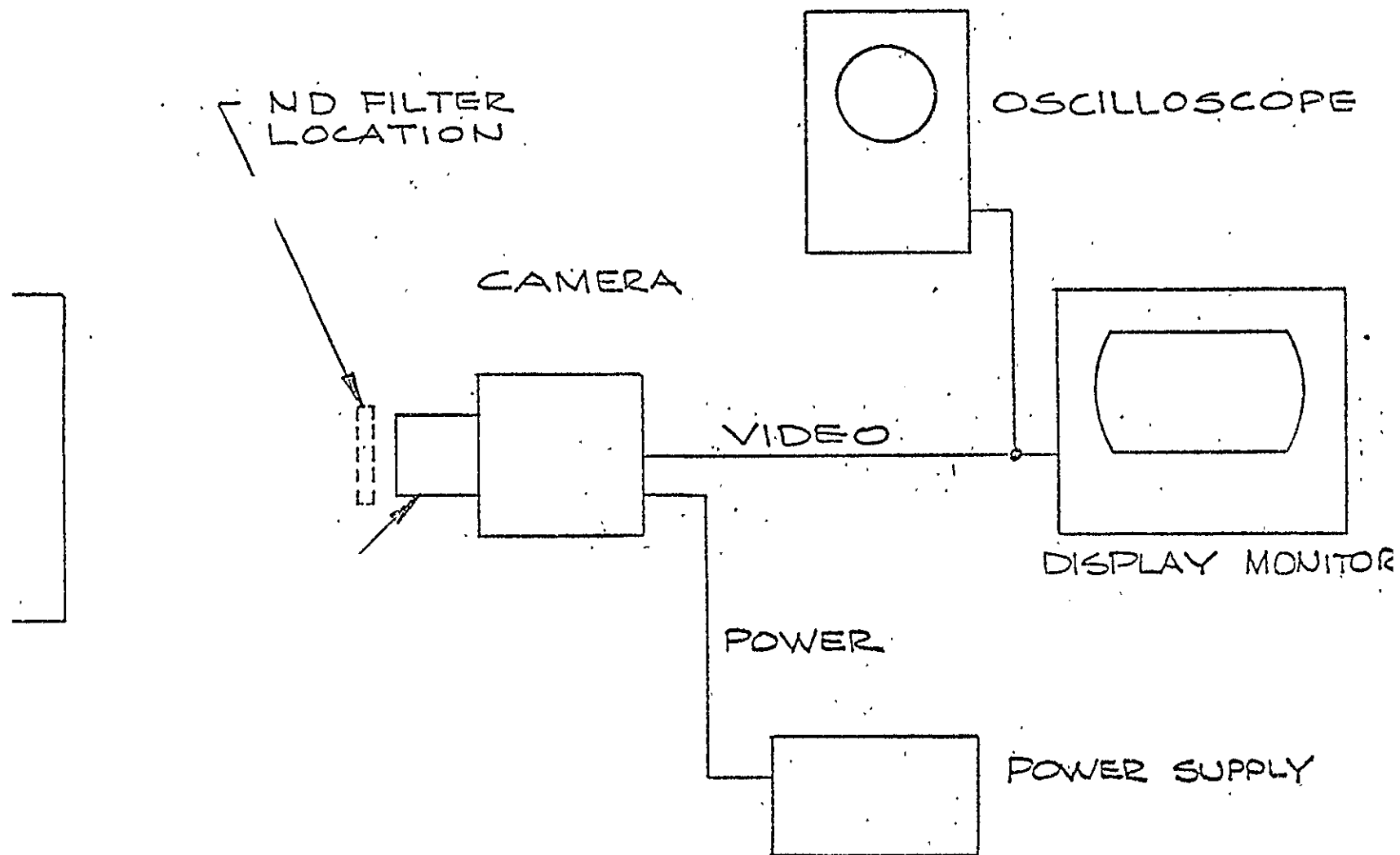


FIGURE 1. SYSTEM BLOCK DIAGRAM

computed f-stop value and the corresponding "B" value on the data sheet.

4.3 Aspect Ratio and Resolution

With the light calibration condition defined by 4.2 (e) above, and with the camera viewing TP#1, adjust camera alignment and lens focus until the right and left edge marks just touch the corresponding edges of the unblanked display raster.

4.3.1 Aspect Ratio

With conditions as described in 4.3 above, the top and bottom edge marks shall coincide with the top and bottom edges of the unblanked scanning pattern within less than 24 scanning lines. Check on data sheet.

4.3.2 Resolution

With conditions as described in 4.3.1, the horizontal resolution shall exceed $0.7 \times 285 = 200$ TV lines/picture height. The vertical resolution shall exceed $0.7 \times 488 = 342$ TV lines/picture height. Record observed values on data sheet.

4.3.3 Resolution Response

Remove TP#1 and insert the spatial frequency test pattern, TP#3, in the light box. Adjust camera alignment and focus to achieve optimum alignment and phasing conditions for the smallest (Nyquist-limit) test bar groups. Use the oscilloscope to view a single line of output video containing test bars at $1/8$, $1/4$, $1/2$ and Nyquist-limit horizontal resolution. Photograph the scope display and attach copies to the data sheets.

4.4 Spots and Blemishes

With the sensor face uniformly illuminated at the level defined by light calibration condition 4.2 (c), locate spots and blemishes by observing the monitor display. Measure amplitudes using the oscilloscope in the line select mode.

A spot or blemish is defined as a video signal transition equal to or greater than 7% of the CCD sensor saturation signal, observed with the sensor uniformly illuminated at a level corresponding to 50% saturation. The size of a spot or blemish shall be determined by counting the number of scan lines on which the transition occurs; i.e., the number of lines per frame on which the transition is greater than 7% of saturation signal.

The total number of white and dark spots shall be less than or equal to:

- 10 spots over 1 but less than or equal to 4 TV lines/frame.
- 2 spots over 4 but less than or equal to 8 TV lines/frame.
- 0 spots over 8 TV lines/frame.
- No horizontal black lines resulting from a failed CCD element shall be allowed. The number and length of vertical black lines resulting from a failed CCD element shall be less than or equal to:
 - 4 lines within the full (unblanked) imaging area
 - 1 line or portion thereof within the central area of 190 (H) X 244 (V) CCD elements
 - 0 lines over 1/4 picture height length within the central area of 293 (H) X 488 (V) CCD elements.

Record the total number of spots and blemishes in each of the above categories on the data sheets.

- Indicates revision 11/78

4.4.1 Dark Current Non-Uniformity

With the light calibration condition defined by 4.2 (e) and with the camera viewing TP#1, check that the channel gains are adjusted to provide a full-scale output (100 IRE units) for a sensor high-light illumination of 0.05 foot-candle. Cover the camera lens such that no light falls on the sensor. Observe the video output on the oscilloscope and check that the output is uniform to within 10 IRE units (71.4mV). Check the data sheet.

4.4.2 Response Non-Uniformity

With the camera viewing TP#1, adjust the voltage input to the light box until the array is uniformly illuminated to the point just below saturation. Observe the video output on the oscilloscope and check that the output is uniform to within 15 IRE units (107.1mV). Check the data sheet.

4.5 Gray Scale and Signal-To-Noise Ratio

Insert the gray scale pattern, TP#2, in the light box. With the sensor illumination conditions as defined by 4.2 (e), verify that ten gray scale steps can be resolved on the monitor display. Check data sheets.

4.5.1 Signal to Noise Ratio

While the camera system is operating as defined in 4.5 above, use the oscilloscope in the line select mode to determine the peak-to-peak signal, V_{p-p} , corresponding to maximum white to minimum dark signal. Record value on data sheets. Without changing camera operating conditions, increase scope gain to observe peak-to-peak

temporal noise variations, N_{p-p} at the dark level signal. Verify that the signal-to-RMS noise ratio, as defined by:

$$SNR = 20 \log (6V_{p-p}/N_{p-p}),$$

is greater than 40dB. Record observed values on data sheets.

4.6 Dynamic Light Range

Remove the test lens and install the Auto-Iris lens assembly. Focus and align the camera to view TP#2, with the light box adjusted to provide approximately 1000 f1 highlights. Verify that useful imaging quality is observed, with the output video signal maintained constant within ± 3 dB, over an illumination range of 1000:1 as determined by placing ND1, and ND2 and ND3 filters in front of the lens aperture. Check on data sheets.

With no ND filters in front of the lens, adjust the intensity of the light box by varying input voltage. Gradually reduce light box intensity until five gray scale steps are just discernible on the monitor display. Measure the highlight level of the test pattern corresponding to five gray step camera performance and record value on data sheets.

4.7 Output Video Forma

With the camera operating as in 4.6, mount the ND2 filter in front of the lens. Using the oscilloscope, examine the output composite video waveform. Verify the following:

Composite Video polarity	Black Negative
Blanked picture signal, with setup (nominally 100 IRE units)	0.714 $\pm$ 0.1V

Sync signal (from 0VDC, Ref.) $0.286 \pm 0.05V$

Setup, blanking level to reference black level, (IRE units) 7.5 ± 0.05

Record observations on data sheets.

Examine the sync signal and verify that the H and V blanking period and waveforms conform with EIA RS-170 specifications. Check on data sheets.

4.8 Power Supply

Using a Fluke digital voltmeter Model 8600A, measure the camera power supply input voltage. The reading shall be $+28VDC \pm 4VDC$. Verify camera system operation with supply variations from 24V to 32V. Check on data sheets.

4.9 Camera Interfaces

Verify that the camera will operate from an external sync by performing the following:

Connect the composite sync output of the Tektronix Model 144 test signal generator to the upper trace of the oscilloscope while triggering the oscilloscope externally from this signal. Connect the output of the camera to the lower trace of the oscilloscope. With the camera operating on internal sync, the lower trace will free run while the upper trace will be stationary. When the composite sync output of the Tektronix signal generator is connected to the external sync input of the camera, the lower trace of the oscilloscope should become stationary. At this point,

verify that the camera is in sync with the Tektronix signal generator by observing that the vertical sync intervals of each waveform on the oscilloscope have the same number of equalizing pulses. Check on data sheet.

4.10 Brightness Overload (Blooming)

Remove the light box assembly and replace with a reflector-type lamp fixture containing a frosted 100 watt lamp bulb. With the lamp voltage supply OFF, align the camera to directly view the lamp and the large diameter open end of the reflector. Adjust camera viewing distance and lens focus until the reflector housing diameter just fills the width of the display screen.

Using a variable AC source, gradually increase lamp voltage to 120VAC while observing the video display. Verify that details of the lamp and reflector can be observed, including portions of the lamp brand labeling, with the lamp at full intensity. Check on data sheets and attach photographs of the video display with and without lamp voltage applied. Measure peak brightness of the lamp operating at 120VAC and record on data sheets.

NASA/JSC ADVANCED DESIGN SOLID STATE
TELEVISION CAMERA SYSTEM
PREDELIVERY ACCEPTANCE TEST DATA SHEETS

Sheet 1 of 4

3.0 Camera Serial Number _____

Lens Serial Number _____

4.2 Light Level Calibration

b) Test pattern highlight brightness _____ f1

c) "f" number for one stop below saturation: f _____

d) $I_H = \frac{B \times 0.8}{4f^2 \times 100} = \text{_____} f_c$ (1 stop below saturation)

e) $f = \left(\frac{B \times 0.8}{4 \times 5 \times 10^{-2} \times 10^{-2}} \right)^{1/2}$

B = _____

f = _____

4.3 Aspect Ratio and Resolution

4.3.1 Unblanked vertical scan alignment: *

less than 24 scan lines _____ Accept

more than 24 scan lines _____ Reject

4.3.2 Resolution *

Horizontal Resolution _____ TVL/PH ≥ 200 _____ Accept

< 200 _____ Reject

Vertical Resolution _____ TVL/PH ≥ 342 _____ Accept

< 342 _____ Reject

4.3.3 Resolution Response

See Photograph

* Record observed values

4.4 Spots and Blemishes

_____ over 1 but less than or equal to 4 TVL/frame	≤ 10	_____ Accept
	> 10	_____ Reject
_____ over 4 but less than or equal to 8 TVL/frame	≤ 2	_____ Accept
	2	_____ Reject
_____ over 8 TVL	0	_____ Accept
	0	_____ Reject

▶ NOTE: Horizontal black lines are counted as blemishes in the size category equivalent in defect area to circular spots of the sizes indicated above. Vertical black line blemishes are counted as indicated below:

Four lines or less in full imaging area	_____ Accept
More than four lines in full imaging area	_____ Reject
_____ Lines within central 190 (H) X 244 (V) element area	≤ 1 _____ Accept
	> 1 _____ Reject
_____ Lines over 1/4 picture height length within central 293 (H) X 488 (V) element area	0 _____ Accept
	0 _____ Reject

4.4.1 Dark Current Non-Uniformity*

Video output non-uniformity ≤ 10 IRE units (71.4mV)	_____ Accept
Video output non-uniformity > 10 IRE units (71.4mV)	_____ Reject

4.4.2 Response Non-Uniformity*

Response non-uniformity ≤ 15 IRE units (107.1mV)	_____ Accept
Response non-uniformity > 15 IRE units (107.1mV)	_____ Reject

4.5 Gray Scale

Ten gray steps discernible	_____ Accept
Less than 10 steps discernible	_____ Reject

4.5.1 Signal-To-Noise Ratio

Peak-to-peak highlight video signal V_{p-p}	_____
Peak-to-peak temporal noise variations N_{p-p}	_____

* Record observed values

→ Indicates revision 11/78

$$\text{SNR} = 20 \log (6 V_{p-p}/N_{p-p})$$

= _____ dB

≥ 40dB _____ Accept

< 40dB _____ Reject

4.6

Dynamic Light Range

Highlight video signal, no ND, V0 = _____

Highlight video signal, ND1, V1 = _____

Highlight video signal, ND2, V2 = _____

Highlight video signal, ND3, V3 = _____

V1, V2 and V3 within ±3dB of V0 _____ Accept

V1, V2 or V3 not within ±3dB of V0 _____ Reject

Five gray scale steps discernible with light box.

highlight at _____ fl.

4.7

Output Video Format

Composite video polarity, black negative _____ Accept

black positive _____ Reject

Blanked picture signal with setup, Vpp = _____ V;

0.614 to 0.814 _____ Accept

< 0.614 to >0.814 _____ Reject

Sync signal (from CVDC Ref.) Vs = _____ V

0.236V to 0.336V _____ Accept

< 0.236V to >0.336V _____ Reject

Setup, blanking level to ref. black level _____ IRE units*

*Passes spec with 25% average picture level

7.0 to 8.0 IRE units _____ Accept

< 7.0 to >8.0 IRE units _____ Reject

Sync signal waveform per EIA RS-170 _____ Accept

_____ Reject

4.8 Power Supply

Power supply input voltage _____ 28VDC

Camera system operates at 24VDC and 32VDC _____ Accept

Camera system does not operate at 24VDC and 32VDC _____ Reject

4.9 Camera Interfaces

Camera system operates from an external sync _____ Accept

Camera system does not operate from an external sync. _____ Reject

1.10 Blooming

Detail of lamp and-reflector observed with lamp voltage at
120 VAC _____ Accept

Details of lamp and reflector not observed _____ Reject

Test conducted by _____

Test witnessed by _____

Date _____

APPENDIX A

SECTION II
ENVIRONMENTAL TESTS

1.0 SCOPE

A prototype development test program will be conducted by the FSG Integration & Test Section to determine the compatibility of the Solid State TV Camera with the stringent environmental stresses encountered in a space mission. This evaluation will be performed in a step stress program such that the camera's operation can be monitored under several degrees of stress to accurately define the limits of its performance capabilities.

Baseline performance measurements will be conducted under standard conditions, before and after each environmental test. These measurements will provide a comparative basis for evaluation of the measurements performed during the environmental tests requiring camera operation and provides a means of evaluating any performance degradation as a result of the non-functional environmental exposures.

2.0 GENERAL REQUIREMENTS

2.1 Standard Conditions

Unless otherwise specified, the tests shall be conducted under the following standard test conditions:

Altitude - Local Atmosphere

Temperature - 77°F ±9°F

Humidity - Room ambient up to 90% RH

2.2 Calibration

All test equipment shall be verified for proper calibration prior to use and no equipment shall be used if the expiration date has

been reached. The expiration date shall be displayed on all test equipment.

2.3 Volume

The volume of the test facility and position of the test item shall be such that the bulk of the equipment under test shall not interfere with the generation and maintenance of test conditions.

2.4 Acceptance Testing

Prior to the start of the environmental condition testing, the Camera System shall have satisfactorily completed the Acceptance Tests.

2.5 Temperature Stabilization

Temperature stabilization will be considered established when 75% of the thermocouples are within 5°F of the specified temperature for two (2) successive readings separated by a 15 minute interval.

2.6 Data

Applicable electrical performance data shall be recorded before, after and where required during environmental testing per the applicable performance test procedure.

3.0 ENVIRONMENTAL TESTS

3.1 Temperature

3.1.1 Scope

This test will be conducted to determine the effects of high and low temperature combined with pressure, as encountered during a space mission, on camera performance.

3.1.2 Test Procedure

- The camera, with the 25mm test lens and power supply, will be installed on a copper thermal shroud and cold plate which will be mounted within the vacuum test system. The cold plate and shroud will be connected via feed-through ports to a liquid nitrogen supply. This system will circulate liquid nitrogen through the cooling lines on the cold plate and thermal shroud wall. High temperatures are achieved by strip heaters secured to the copper shroud and cold plate.

The vacuum requirements will be achieved by the use of mechanical vacuum pumps as well as oil diffusion pumps. Pressure measurements will be made with an ionization gauge. Temperature measurements will be made with thermocouples secured to the camera case, power supply and cold plate and will be monitored and recorded with the use of a digital temperature measurement system.

Prior to the initiation of the environmental conditions, performance measurements in accordance with Section IV (Performance Tests during temperature) will be made on the camera to provide a comparative basis for performance evaluation. During these tests, the camera will be looking through the pyrex glass of the vacuum chamber wall. Following these tests the camera will be de-energized and the chamber pressure will be reduced to and maintained at 1×10^{-6} Torr. This pressure has been chosen due to the limitations of the chamber pumping system and is considered a standard pressure for space simulations.

→ Indicates revision 11/78

When the pressure conditions have been stabilized, the cold plate temperature will be increased to $+131^{\circ}\text{F}$ and maintained at this temperature for a period of six hours. Following this six hour exposure, the system will be energized for a period of one hour and a series of comparative performance measurements will be made in accordance with Section IV. If camera operation proves satisfactory, the temperature of the cold plate will be increased to 160°F and the one hour operation period and comparative tests repeated. If operation is successful, the temperature will again be increased to 200°F and a two hour operating test will be performed, followed by a series of comparative measurements in accordance with Section IV.

The camera will then be de-energized and the cold plate temperature will be reduced to -65°F and maintained at these conditions for a period of two hours. Following the two hour exposure, the cameras will be energized for a period of one hour and a series of comparative measurements will be made. If camera operation proves to be satisfactory, the temperature of the cold plate will be reduced to -100°F and the one hour operation period repeated.

If camera operation is satisfactory the temperature will again be reduced in 25° increments and the one hour operating test and comparative measurements repeated at each increment. The minimum temperature will be -200°F . At the minimum temperature that the camera operation is deemed satisfactory, the camera will be maintained non operating for six hours. Following the six hour

exposure the camera will be energized for a period of two hours and a series of comparative measurements will be made in accordance with Section IV.

At the conclusion of the exposure period, the chamber and cold plate will be returned to standard conditions and the camera system will be examined for any evidence of damage as a result of the environmental exposure. The camera system will then be subjected to a full performance test.

3.2 Random Vibration (Non-Operative)

3.2.1 Scope

This test will be conducted to determine the ability of the camera system to survive the dynamic stresses of spacecraft vibration. The camera system will be de-energized during the exposure period.

3.2.2 Procedure

The camera system will be mounted on a vibration fixture which will be secured to an electrodynamic vibration exciter. For these tests, the zoom lens will be replaced with a mass model simulating the mass distribution and mounting features of the zoom lens assembly. In addition, the CCD module will be a test module equivalent to the deliverable camera module except for spot and blemish characteristics. The vibration fixture will be designed to minimize resonant excitations within the test frequency range. The vibration input will be monitored by several accelerometers which will be secured to the vibration fixture adjacent to the

fixture/specimen interface. The vibration inputs will be provided by a digital vibration control system which will also provide accurate control and monitoring of the acceleration spectral density. A fourier analysis will be performed on the vibration spectrum to determine compliance with the spectral content of the specification. Following each axis of vibration, the camera system will be operated to verify proper performance.

ACCELERATION SPECTRAL DENSITY

20 to 70 Hz	Increasing, at 9dB/octave to $0.4g^2/\text{Hz}$ at 70 Hz
70 to 500 Hz	Constant at $0.4g^2/\text{Hz}$
500-2000 Hz	Decreasing, at 6dB/octave from $0.4g^2/\text{Hz}$ at 500 Hz

The vibration application will be performed in accordance with the following table:

<u>COMPOSITE</u>	<u>DURATION</u>	<u>)-500Hz (G^2/Hz)</u>
4.5 grms (-12db)	30 seconds	.025
6.4 grms (-9db)	30 seconds	.05
9.0 grms (-6db)	30 seconds	.1
12.7grms (-3db)	30 seconds	.2
18.1grms (0db)	34 minutes	.4

These tests will be performed in the system's three mutually perpendicular axes for a total time of 34 minutes exposure per axis.

At the conclusion of the last exposure, the system will be examined for evidence of damage and subjected to a complete performance test to verify proper operation.

3.3 Shock.

3.3.1 Scope

The shock test is conducted to determine the effect of the shock pulse on the camera system during the non-operational phases of the mission.

3.3.2 Test Procedure

The camera system, configured as described in paragraph 3.2.2, will be secured to the vibration fixture which will be attached to the electrodynamic vibration exciter. An accelerometer will be mounted on the fixture adjacent to the fixture/specimen interface to monitor the shock input level. The system will be de-energized during the shock exposure period.

A digital transient control system will be used to synthesize the shock pulse and provide the input to the exciter. The camera system will be subjected to a terminal peak sawtooth shock pulse of 11 milliseconds duration and 20 g peak amplitude, in each of six directions along the system's three orthogonal axes.

At the conclusion of the exposure period, the camera will be examined for evidence of damage and subjected to a complete performance test to verify proper operation.

3.4 Acceleration

3.4.1 Scope

The acceleration test is conducted to determine the effects of G loading, as encountered during a space mission, on the camera system.

3.4.2 Test Procedure

The camera system, configured as described in paragraph 3.2.2, will be secured to a centrifuge with a rotating arm of sufficient length to maintain the acceleration gradient within $\pm 0.5g$. The camera system will be de-energized during this test.

The environmental exposure will consist of five minute exposure to an acceleration level of $5.0g$'s in each direction along the system's three orthogonal axis.

At the conclusion of the test period, the camera system will be examined for evidence of damage and subjected to a complete performance check to verify proper operation.

APPENDIX A

SECTION III

PERFORMANCE TEST PROCEDURE

1.0 SCOPE

The purpose of this Performance Test Procedure is to verify that the operation of the camera system has not been affected by the environmental tests. The camera system will be tested for proper operation at the beginning of the environmental test sequence and after each stage of the environmental tests, while corresponding data will be recorded on the data sheets. Only camera parameters that may change due to environmental testing will be checked.

2.0 TEST EQUIPMENT REQUIRED

The following test equipment will be used to verify the performance of the television camera system components:

- a) Fluke Digital Voltmeter, Model 8660A
- b) CCD Resolution Test Target, 4x3 aspect ratio, TP#1
- c) Logarithmic Gray Scale Test Target, TP#2
- d) Tektronix Light Meter, Model J6523
- e) Power Supply, D.C., Power Designs Model 3240, or equivalent
- f) Oscilloscope, Tektronix Model 7704A, or equivalent
- g) Neutral Density Filters, ND1.0, ND2.0 and ND3.0
- h) Tele-Measurement Light Box, Model TELE-PAT III
- i) Test Lens, C-Mount type, 25 mm, f1.4 - f22
- j) Display Monitor, Conrac Model DZA14, or equivalent

The above test equipment will be suitably calibrated when necessary.
Check data sheet.

3.0 VISUAL INSPECTION

Verify that the following equipment comprising the deliverable system is available. Record serial numbers on data sheet.

3.1 Solid State Television Camera Assembly

1 - Camera Electronics Unit

1 - Lens, Schneider Model VGN 2/18-90

4.0 TEST PROCEDURE

The following tests shall be performed while the television system is in a normal operation mode except where otherwise noted.

4.1 System Interconnection

See System Block Diagram, Figure 1.

4.2 Light Level Calibration

- a) Replace the Auto-Iris camera lens with the 25mm test lens.
- b) Adjust the voltage input to the light box to obtain approximately 500 f1 highlights with the test patterns in position. Record reading on the data sheets.
- c. Place the ND2 filter in front of the test lens. Set the iris at f/4. Adjust camera alignment and lens focus until the test pattern image (TP#1) just fills the full width of the unblanked display raster. Adjust the lens iris to approximately one f stop below CCD saturation. Record f stop setting on the data sheets.
- d. Compute sensor highlight illumination I_H from the formula:

$$I_H = \frac{B \times 0.8}{4f^2 \times 100} \quad (\text{fc})$$

where B is the TP highlight value, f is the f-stop value.

Record the computed I_H value for one-stop below saturation on the data sheet.

- e. Compute the f-stop value required to achieve $I_H = 5 \times 10^{-2} \text{fc}$ at the sensor faceplate with the ND2 filter in front of the lens. Adjust "B" value of light box if necessary. Record the

computed F-stop value and the corresponding "B" value on the data sheet.

4.3 Resolution

With the light calibration condition defined by 4.2(e) above, and with the camera viewing TP#1, adjust camera alignment and lens focus until the right and left edge marks just touch the corresponding edges of the unblanked display raster. After adjusting for best lens focus, the horizontal resolution shall exceed $0.7 \times 285 = 200$ TV lines/picture height. The vertical resolution shall exceed $0.7 \times 480 = 342$ TV lines/picture height. Record observed values on data sheet.

4.4 Dark Current Non-Uniformity

With the light calibration condition defined by 4.2 (e), and with the camera viewing TP#1, check that the channel gains are adjustable to provide a full-scale output (100 IRE units) for a sensor highlight illumination of 0.05 foot-candle. Cover the camera lens such that no light falls on the sensor. Observe the video output on the oscilloscope and check that the output is uniform to within 10 IRE units (71.4mV). Check the data sheet.

4.5 Signal-to-Noise Ratio

While the camera system is operating as defined in 4.3 above, use the oscilloscope in the line select mode to determine the peak-to-peak signal, V_{p-p} , corresponding to maximum white to minimum dark signal. Record value on data sheets. Without changing camera

operating conditions, increase scope gain to observe peak-to-peak temporal noise variations, N_{p-p} at the dark level signal. Verify that the signal-to-RMS noise ratio, as defined by:

$$SNR = 20 \log (6V_{p-p}/N_{p-p}),$$

is greater than 40dB. Record observed values on data sheets.

4.6 Automatic Light Control (ALC)

NOTE: Perform (a) for the initial performance test. Perform (b) for the remaining performance tests.

- (a) With the light level as defined by 4.2(e), measure the ALC voltage with a Fluke DVM, Model 8600A. Record value on data sheet.
- (b) With the light level as defined by 4.2(e), measure the ALC voltage with a Fluke DVM, Model 8600A. Record on data sheet. This value should be within $\pm 5\%$ of the value in (a) above. Check on data sheet.

4.7 Output Video Format

With the camera operating as in 4.2(e), use the oscilloscope to examine the output composite video waveform. Verify the following:

Composite Video polarity	Black negative
Blanked picture signal, with setup (nominally 100 IRE units)	$0.714 \pm 0.1V$
Sync signal (from 0VDC, Ref.)	$0.286 \pm 0.05V$
Setup, blanking level to reference black level, (IRE units)	7.5 ± 0.05

Record observations on data sheets.

Examine the sync signal and verify that the H and V blanking periods and waveforms conform with EIA RS-170 specifications. Check on data sheets.

4.8 Power Supply

Using a Fluke digital voltmeter, Model 8600A, measure the camera power supply input voltage. The reading shall be $+28\text{VDC} \pm 4\text{VDC}$. Verify camera system operation with supply variations from 24V to 32V. Check on data sheet. Measure the input power to the camera at 28VDC. With the CCD cooler on and lens motor off, it should be $\leq 890\text{mA}$. (This corresponds to $\leq 25\text{W}$). Check on data sheet.

→ Indicates revision 11/78

APPENDIX A

SECTION IV

PERFORMANCE TEST DURING TEMPERATURE TESTS

With conditions as defined by 4.2 (e) and Figure 1 of the Acceptance Test, monitor the following parameters and record the values that correspond to the maximum deviation from the values obtained before the temperature test:

Blanked picture signal with setup, $V_{p-p} = \underline{\hspace{2cm}}$ V

Sync signal (from 0VDC, Ref), $V_s = \underline{\hspace{2cm}}$ V

Setup, blanking level to ref. blank level $\underline{\hspace{2cm}}$ V

During each step of the temperature test, a determination based on monitor presentation and the above values will be made as to whether the next step of the temperature test should be performed.

APPENDIX B

PREDELIVERY TESTS ON ADVANCED DESIGN SSTV CAMERA SYSTEM

TEST REPORT:	QA Report No. 1651
TEST CONDUCTED:	Acceptance Tests Temperature Random Vibration Acceleration Shock
TEST ITEM:	Solid State Television Camera System
QUANTITY OF ITEMS TESTED	Two (2)
DATE TESTING STARTED:	28 September 1978
DATE TESTING COMPLETED:	4 December 1978
CONTRACT NO.:	NAS9-15407
FIS JOB NO.:	6186

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FAIRCHILD IMAGING SYSTEMS
A Division of Fairchild Camera and Instrument Corporation

1.0 ACCEPTANCE TESTS

in accordance with QA Report No. 1615 Rev. B

The acceptance tests were satisfactorily performed on the two deliverable camera systems. The results were recorded on the data sheets following this page.

Unit Tested:

Solid State Television Camera

NASA/JSC ADVANCED DESIGN SOLID STATE
TELEVISION CAMERA SYSTEM
PREDELIVERY ACCEPTANCE TEST DATA SHEETS

Sheet 1 of 4

3.0 Camera Serial Number 6186-001

Lens Serial Number 13-260-041

4.2 Light Level Calibration

b) Test pattern highlight brightness 502 f1

c) "f" number for one stop below saturation: f f5.6

d) $I_H = \frac{B \times 0.8}{4f^2 \times 100} = \underline{.032}$ fc (1 stop below saturation)

e) $f = \left(\frac{B \times 0.8}{4 \times 5 \times 10^{-2} \times 10^{-2}} \right)^{1/2}$

B = 400 ft. lam.

f = f4

4.3 Aspect Ratio and Resolution

4.3.1 Unblanked vertical scan alignment: * (14.6 lines)

less than 24 scan lines ✓ FCI 976 Accept

more than 24 scan lines _____ Reject

4.3.2 Resolution *

Horizontal Resolution 300 TVL/PH ≥ 200 ✓ FCI 976 Accept

< 200 _____ Reject

Vertical Resolution 400 TVL/PH ≥ 342 ✓ FCI 976 Accept

< 342 _____ Reject

4.3.3 Resolution Response

See Photograph

Record observed values

4.4 Spots and Blemishes

2 over 1 but less than or equal to 4 TVL/frame ≤ 10 FCI 976 Accept
 > 10 _____ Reject

0 over 4 but less than or equal to 8 TVL/frame ≤ 2 FCI 976 Accept
 > 2 _____ Reject

0 over 8 TVL ≤ 0 FCI 976 Accept
 _____ > 0 _____ Reject

→ NOTE: Horizontal black lines are counted as blemishes in the size category equivalent in defect area to circular spots of the sizes indicated above. Vertical black line blemishes are counted as indicated below:

1 Four lines or less in full imaging area FCI 976 Accept
 More than four lines in full imaging area _____ Reject

0 Lines within central 190 (H) X 244 (V) element area ≤ 1 FCI 976 Accept
 > 1 _____ Reject

0 Lines over 1/4 picture height length within central 293 (H) X 488 (V) element area ≤ 0 FCI 976 Accept
 > 0 _____ Reject

4.4.1 Dark Current Non-Uniformity* (.050v) WITH IR FILTER
 Video output non-uniformity ≤ 10 IRE units (71.4mV) FCI 976 Accept
 Video output non-uniformity > 10 IRE units (71.4mV) _____ Reject

4.4.2 Response Non-Uniformity* (.060v)
 Response non-uniformity ≤ 15 IRE units (107.1mV) FCI 976 Accept
 sponse non-uniformity > 15 IRE units (107.1mV) _____ Reject

4.5 Gray Scale

Ten gray steps discernible ✓ FCI 976 Accept
 Less than 10 steps discernible _____ Reject

4.5.1 Signal-To-Noise Ratio

Peak-to-peak highlight video signal V_{p-p} .780v
 Peak-to-peak temporal noise variations N_{p-p} .010v

* Record observed values

→ Indicates revision 11/78

$$\text{SNR} = 20 \log (6 V_{p-p} / N_{p-p})$$

$$= \underline{52} \text{ dB}$$

 $\geq 40\text{dB}$ FCI 976 Accept

 $< 40\text{dB}$ _____ Reject

4.6

Dynamic Light RangeHighlight video signal, no ND, $V_0 = \underline{.760}$ ✓Highlight Video signal, ND1, $V_1 = \underline{.760}$ ✓Highlight video signal, ND2, $V_2 = \underline{.760}$ ✓Highlight video signal, ND3, $V_3 = \underline{.740}$ ✓ V_1, V_2 and V_3 within $\pm 3\text{dB}$ of V_0 ✓ FCI 976 Accept V_1, V_2 or V_3 not within $\pm 3\text{dB}$ of V_0 _____ RejectFive gray scale steps discernible with light box
highlight at 2.0 fl.

4.7

Output Video FormatComposite video polarity, black negative ✓ FCI 976 Accept

black positive _____ Reject

Blanked picture signal with setup, $V_{pp} = \underline{.760}$ V;0.614 to 0.814 FCI 976 Accept

< 0.614 to > 0.814 _____ Reject

ync signal (from 0VDC Ref.) $V_s = \underline{.280}$ V0.236V to 0.336V FCI 976 Accept

< 0.236V to > 0.336V _____ Reject

Setup, blanking level to ref. black level 7 IRE units*

*Passes spec with 25% average picture level

7.0 to 8.0 IRE units ✓ FCI 976 Accept

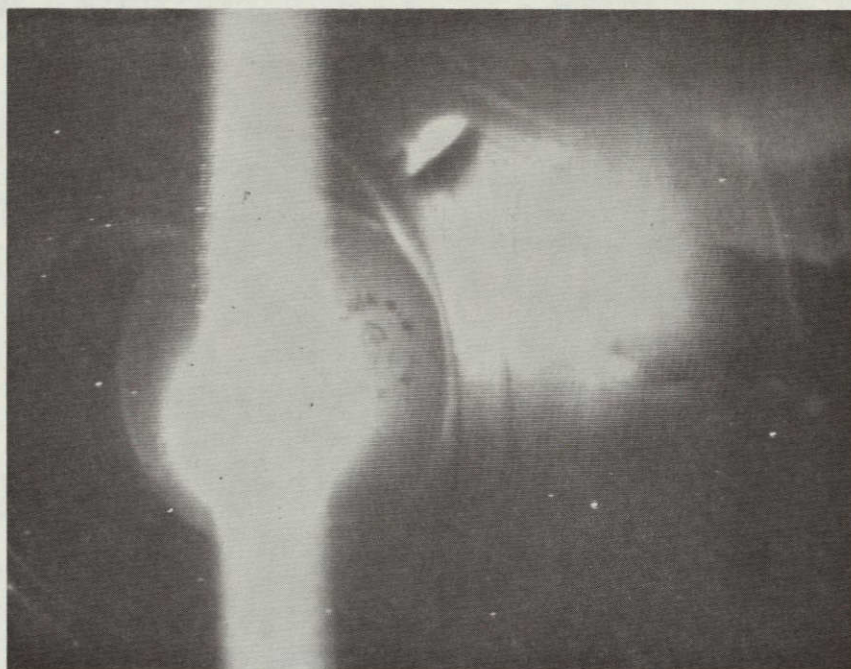
< 7.0 to > 8.0 IRE units _____ Reject

Sync signal waveform per EIA RS-170 ✓ FCI 976 Accept

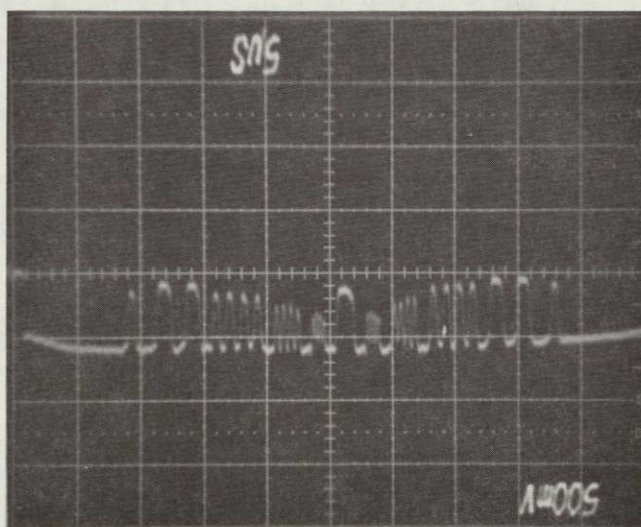
_____ Reject

4.8 Power SupplyPower supply input voltage ☒ 28VDCCamera system operates at 24VDC and 32VDC ☒ AcceptCamera system does not operate at 24VDC and 32VDC ☐ Reject4.9 Camera InterfacesCamera system operates from an external sync ☒ AcceptCamera system does not operate from an external sync ☐ Reject4.10 BloomingDetail of lamp and reflector observed with lamp voltage at
120 VAC ☒ AcceptDetails of lamp and reflector not observed ☐ RejectTest conducted by E. MisuraTest witnessed by K. W. Lareau FCI 976Date 10-2-78

PARA. 4.10 BLOOMING 120 VAC LAMP VOLTAGE



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PARA. 4.3.3 RESOLUTION RESPONSE



NASA/JSC ADVANCED DESIGN SOLID STATE
TELEVISION CAMERA SYSTEM
PREDELIVERY ACCEPTANCE TEST DATA SHEETS

Sheet 1 of 4

3.0 Camera Serial Number 6186-001

Lens Serial Number 13-260-041

4.2 Light Level Calibration

b) Test pattern highlight brightness 502 f1

c) "f" number for one stop below saturation: f 5.6

d) $I_H = \frac{B \times 0.8}{4f^2 \times 100} = \underline{.032}$ fc (1 stop below saturation)

e) $f = \left(\frac{B \times 0.8}{4 \times 5 \times 10^{-2} \times 10^{-2}} \right)^{1/2}$

B = 400 ft. lam.

f = f4

4.3 Aspect Ratio and Resolution

4.3.1 Unblanked vertical scan alignment: *

less than 24 scan lines FCI 976 Accept

more than 24 scan lines _____ Reject

4.3.2 Resolution *

Horizontal Resolution 250 TVL/PH ≥ 200 FCI 976 Accept

< 200 _____ Reject

Vertical Resolution 375 TVL/PH ≥ 342 FCI 976 Accept

< 342 _____ Reject

4.3.3 Resolution Response

See Photograph

* Record observed values

4.4 Spots and Blemishes

<u>2</u>	over 1 but less than or equal to 4 TVL/frame	≤ 10	<u>FCI 976</u> Accept
		> 10	Reject
<u>0</u>	over 4 but less than or equal to 8 TVL/frame	≤ 2	<u>FCI 976</u> Accept
		> 2	Reject
<u>0</u>	over 8 TVL	≤ 0	<u>FCI 976</u> Accept
		> 0	Reject

→ NOTE: Horizontal black lines are counted as blemishes in the size category equivalent in defect area to circular spots of the sizes indicated above. Vertical black line blemishes are counted as indicated below:

	Four lines or less in full imaging area	<u>FCI 976</u> Accept
	More than four lines in full imaging area	Reject
<u>1</u>	Lines within central 190 (H) X 244 (V) element area	≤ 1 <u>FCI 976</u> Accept
		> 1 Reject
<u>0</u>	Lines over 1/4 picture height length within central 293 (H) X 488 (V) element area	≤ 0 <u>FCI 976</u> Accept
		> 0 Reject

4.4.1 Dark Current Non-Uniformity* (.050v)

Video output non-uniformity ≤ 10 IRE units (71.4mV) FCI 976 Accept
 Video output non-uniformity > 10 IRE units (71.4mV) _____ Reject

4.4.2 Response Non-Uniformity* (.060v) WITH IR FILTER

Response non-uniformity ≤ 15 IRE units (107.1mV) FCI 976 Accept
 Response non-uniformity > 15 IRE units (107.1mV) _____ Reject

4.5 Gray Scale

Ten gray steps discernible ✓ FCI 976 Accept
 Less than 10 steps discernible _____ Reject

4.5.1 Signal-To-Noise Ratio

Peak-to-peak highlight video signal V_{p-p} .760v
 Peak-to-peak temporal noise variations N_{p-p} .012v

* Record observed values

→ Indicates revision 11/78

C-2

$$\text{SNR} = 20 \log (6 V_{p-p} / N_{p-p})$$

$$= \underline{51} \text{ dB}$$

$\geq 40\text{dB}$ FCI 976 Accept
 $< 40\text{dB}$ _____ Reject

4.6 Dynamic Light Range

Highlight video signal, no ND, $V_0 = \underline{.800}$ ✓
 Highlight Video signal, ND1, $V_1 = \underline{.700}$ ✓
 Highlight video signal, ND2, $V_2 = \underline{.700}$ ✓
 Highlight video signal, ND3, $V_3 = \underline{.600}$ ✓
 V_1, V_2 and V_3 within $\pm 3\text{dB}$ of V_0 ✓ FCI 976 Accept
 V_1, V_2 or V_3 not within $\pm 3\text{dB}$ of V_0 _____ Reject

Five gray scale steps discernible with light box
 highlight at 5 fl.

4.7 Output Video Format

Composite video polarity, black negative FCI 976 Accept
 black positive _____ Reject

Blanked picture signal with setup, $V_{pp} = \underline{.680}$ V;
 0.614 to 0.814 ✓ FCI 976 Accept
 < 0.614 to > 0.814 _____ Reject

Sync signal (from 0VDC Ref.) $V_s = \underline{.280}$ V
 0.236V to 0.336V ✓ FCI 976 Accept
 $< 0.236\text{V}$ to $> 0.336\text{V}$ _____ Reject

Setup, blanking level to ref. black level 7 IRE units*

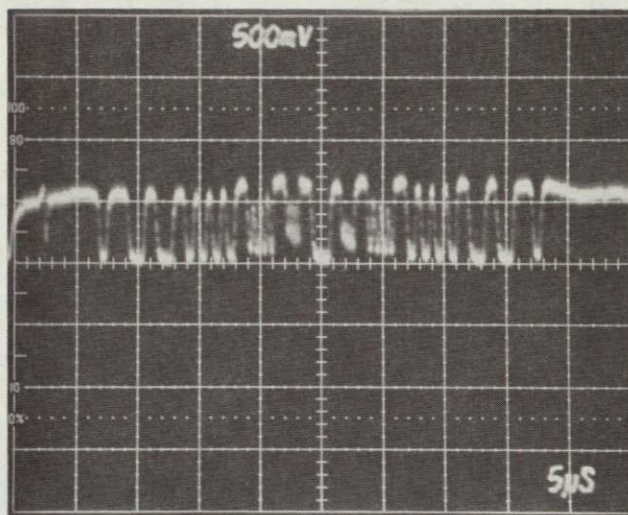
*Passes spec with 25% average picture level

7.0 to 8.0 IRE units ✓ FCI 976 Accept
 < 7.0 to > 8.0 IRE units _____ Reject

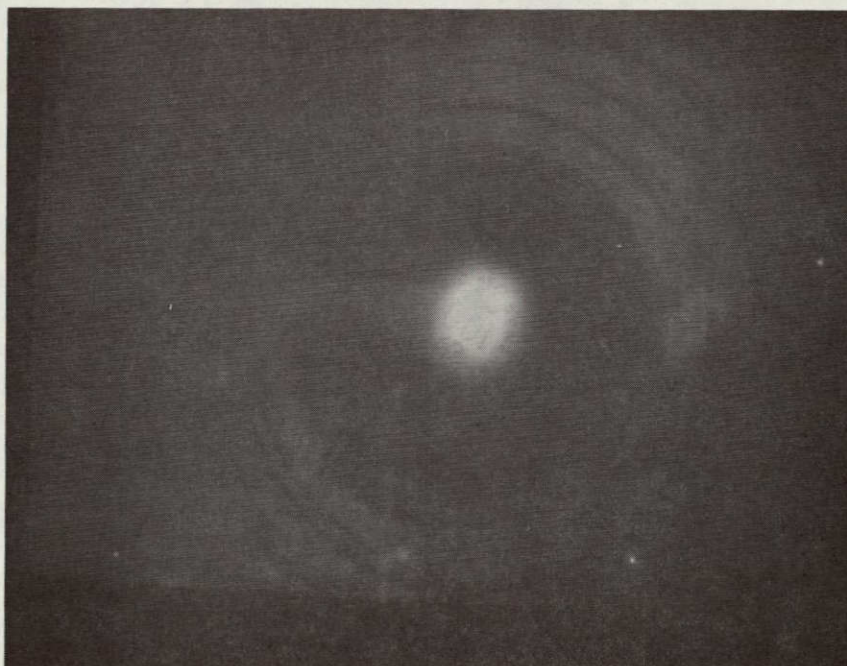
Sync signal waveform per EIA RS-170 ✓ FCI 976 Accept
 _____ Reject

4.8 Power SupplyPower supply input voltage ☒ FCI 976 28VDCCamera system operates at 24VDC and 32VDC ☒ FCI 976 AcceptCamera system does not operate at 24VDC and 32VDC ☒ Reject4.9 Camera InterfacesCamera system operates from an external sync ☒ FCI 976 AcceptCamera system does not operate from an external sync ☐ Reject4.10 BloomingDetail of lamp and-reflector observed with lamp voltage at
120 VAC ☒ FCI 976 AcceptDetails of lamp and reflector not observed ☐ RejectTest conducted by G. MuraTest witnessed by K. Lamm FCI 976Date 12-1-78

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PARA. 4.3.3 RESOLUTION RESPONSE



PARA. 4.10 BLOOMING 120 VAC LAMP VOLTAGE

NASA/JSC ADVANCED DESIGN SOLID STATE
TELEVISION CAMERA SYSTEM
PREDELIVERY ACCEPTANCE TEST DATA SHEETS

Sheet 1 of 4

3.0 Camera Serial Number 6186-002

Lens Serial Number 13-260-051

4.2 Light Level Calibration

b) Test pattern highlight brightness 507 f1

c) "f" number for one stop below saturation: f 2.8

d) $I_H = \frac{B \times 0.8}{4f^2 \times 100} = \underline{.128}$ fc (1 stop below saturation)

e) $f = \left(\frac{B \times 0.8}{4 \times 5 \times 10^{-2} \times 10^{-2}} \right)^{1/2}$

B = 400 ft. Lam.

f = f4

4.3 Aspect Ratio and Resolution

4.3.1 Unblanked vertical scan alignment: * (12.075 lines)

less than 24 scan lines ✓ FCI 976 Accept

more than 24 scan lines _____ Reject

4.3.2 Resolution *

Horizontal Resolution 300 TVL/PH ≥ 200 ✓ FCI 976 Accept

< 200 _____ Reject

Vertical Resolution 400 TVL/PH ≥ 342 ✓ FCI 976 Accept

< 342 _____ Reject

4.3.3 Resolution Response

See Photograph

* Record observed values

4.4 Spots and Blemishes

<u>0</u>	over 1 but less than or equal to 4 TVL/frame	≤ 10	<u>FCI 976</u> Accept
		> 10	Reject
<u>0</u>	over 4 but less than or equal to 8 TVL/frame	≤ 2	<u>FCI 976</u> Accept
		> 2	Reject
<u>0</u>	over 8 TVL		<u>FCI 976</u> Accept
		0	Reject

→ NOTE: Horizontal black lines are counted as blemishes in the size category equivalent in defect area to circular spots of the sizes indicated above. Vertical black line blemishes are counted as indicated below:

	Four lines or less in full imaging area		<u>FCI 976</u> Accept
	More than four lines in full imaging area		Reject
<u>0</u>	Lines within central 190 (H) X 244 (V) element area	$\leq$	<u>FCI 976</u> Accept
		> 1	Reject
<u>0</u>	Lines over 1/4 picture height length within central 293 (H) X 488 (V) element area		<u>FCI 976</u> Accept
		> 0	Reject

4.4.1 Dark Current Non-Uniformity* (.060v) WITH IR FILTER
 Video output non-uniformity ≤ 10 IRE units (71.4mV) FCI 976 Accept
 Video output non-uniformity > 10 IRE units (71.4mV) _____ Reject

4.4.2 Response Non-Uniformity* (.080v)
 Response non-uniformity ≤ 15 IRE units (107.1mV) FCI 976 Accept
 Response non-uniformity > 15 IRE units (107.1mV) _____ Reject

4.5 Gray Scale

Ten gray steps discernible ✓ FCI 976 Accept
 Less than 10 steps discernible _____ Reject

4.5.1 Signal-To-Noise Ratio

Peak-to-peak highlight video signal V_{p-p} .770 ✓
 Peak-to-peak temporal noise variations N_{p-p} .025 ✓

* Record observed values

→ Indicates revision 11/78

$$\text{SNR} = 20 \log (6 V_{p-p} / N_{p-p})$$

$$= \underline{44.7} \text{ dB}$$

 $\geq 40 \text{ dB}$ FCI 976 Accept

 $< 40 \text{ dB}$ _____ Reject

4.6

Dynamic Light RangeHighlight video signal, no ND, $V_0 = \underline{.780 \text{ v}}$ Highlight Video signal, ND1, $V_1 = \underline{.740 \text{ v}}$ Highlight video signal, ND2, $V_2 = \underline{.740 \text{ v}}$ Highlight video signal, ND3, $V_3 = \underline{.650 \text{ v}}$ V_1, V_2 and V_3 within $\pm 3 \text{ dB}$ of V_0 ☒ FCI 976 Accept V_1, V_2 or V_3 not within $\pm 3 \text{ dB}$ of V_0 _____ RejectFive gray scale steps discernible with light box
highlight at 2.6 fl.

4.7

Output Video FormatComposite video polarity, black negative ☒ FCI 976 Accept

black positive _____ Reject

Blanked picture signal with setup, $V_{pp} = \underline{.760 \text{ v}}$ 0.614 to 0.814 ☒ FCI 976 Accept < 0.614 to > 0.814 _____ RejectSync signal (from 0VDC Ref.) $V_s = \underline{.280 \text{ v}}$ 0.236V to 0.336V ☒ FCI 976 Accept $< 0.236 \text{ V}$ to $> 0.336 \text{ V}$ _____ RejectSetup, blanking level to ref. black level 7 IRE units*

*Passes spec with 25% average picture level

7.0 to 8.0 IRE units ☒ FCI 976 Accept < 7.0 to > 8.0 IRE units _____ RejectSync signal waveform per EIA RS-170 ☒ FCI 976 Accept

_____ Reject

4.8 Power Supply

Power supply input voltage ✓ FCI 976 28VDC

Camera system operates at 24VDC and 32VDC ✓ FCI 976 Accept

Camera system does not operate at 24VDC and 32VDC ~~FCI 976~~ Reject

4.9 Camera Interfaces

Camera system operates from an external sync ✓ FCI 976 Accept

Camera system does not operate from an external sync Reject

4.10 Blooming

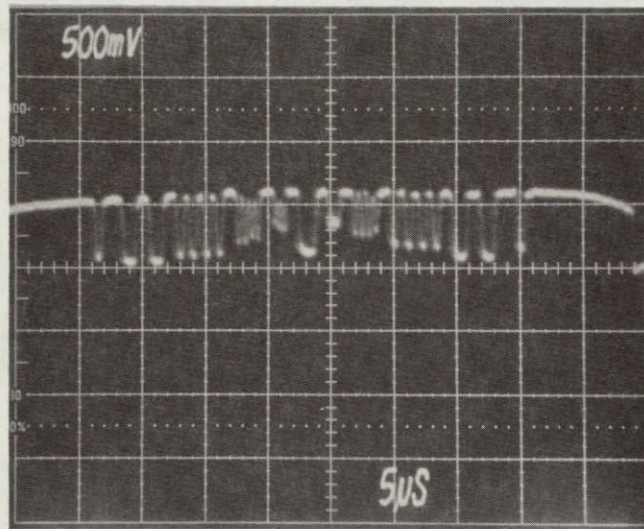
Detail of lamp and-reflector observed with lamp voltage at
120 VAC ✓ FCI 976 Accept

Details of lamp and reflector not observed Reject

Test conducted by G. Miura

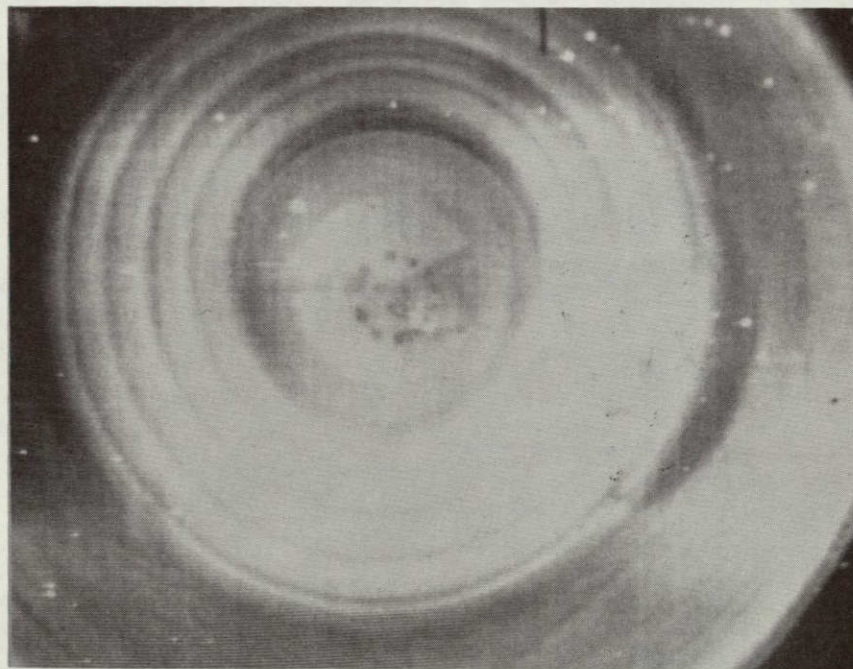
Test witnessed by Kenneth W. FCI 976

Date 12-4-78



PARA. 4.3.3 RESOLUTION RESPONSE

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PARA. 4.10 BLOOMING 120 VAC LAMP VOLTAGE

2.0 RANDOM VIBRATION

2.1 TEST EQUIPMENT (or equivalent)

Vibration System
MB Electronics
Model: C210

Vibration Control System
Hewlett Packard
Model: 5425A

Accelerometer
Endevco
Type 2215

Charge Amplifier
Unholtz-Dickie
Model: 8PMCV

2.2 TEST SETUP

The camera system was mounted on a vibration fixture which was secured to an electrodynamic vibration exciter. For this test the zoom lens was replaced with a mass model simulating the mass distribution and mounting means of the zoom lens assembly. An accelerometer was mounted on the fixture adjacent to the fixture/specimen interface to monitor the vibration input level. The system was de-energized during the vibration exposure period. A photograph of the test setup is included as Figure 1.

2.3 TEST PROCEDURE

Random vibration was applied at the following levels for 34 minutes in each axis:

Acceleration Spectral Density

20 to 70 Hz	Increasing, at 9dB/octave, to $0.4g^2/\text{Hz}$ at 70 Hz
70 to 500 Hz	Constant at $0.4g^2/\text{Hz}$
500 to 2000 Hz	Decreasing, at 6dB/octave, from $0.4^2g/\text{Hz}$ at 500 Hz

The vibration application was performed in accordance with the following table:

<u>Composite</u>	<u>Duration</u>
4.5 grms (-12dB)	30 seconds
6.4 grms (-9dB)	30 seconds
9.0 grms (-6dB)	30 seconds
12.7 grms (-3dB)	30 seconds
18.1 grms (0dB)	34 minutes

Following each axis of vibration, the camera system was operated to verify performance. Post test plots of the power spectral density are included as Figures 2, 3 and 4.

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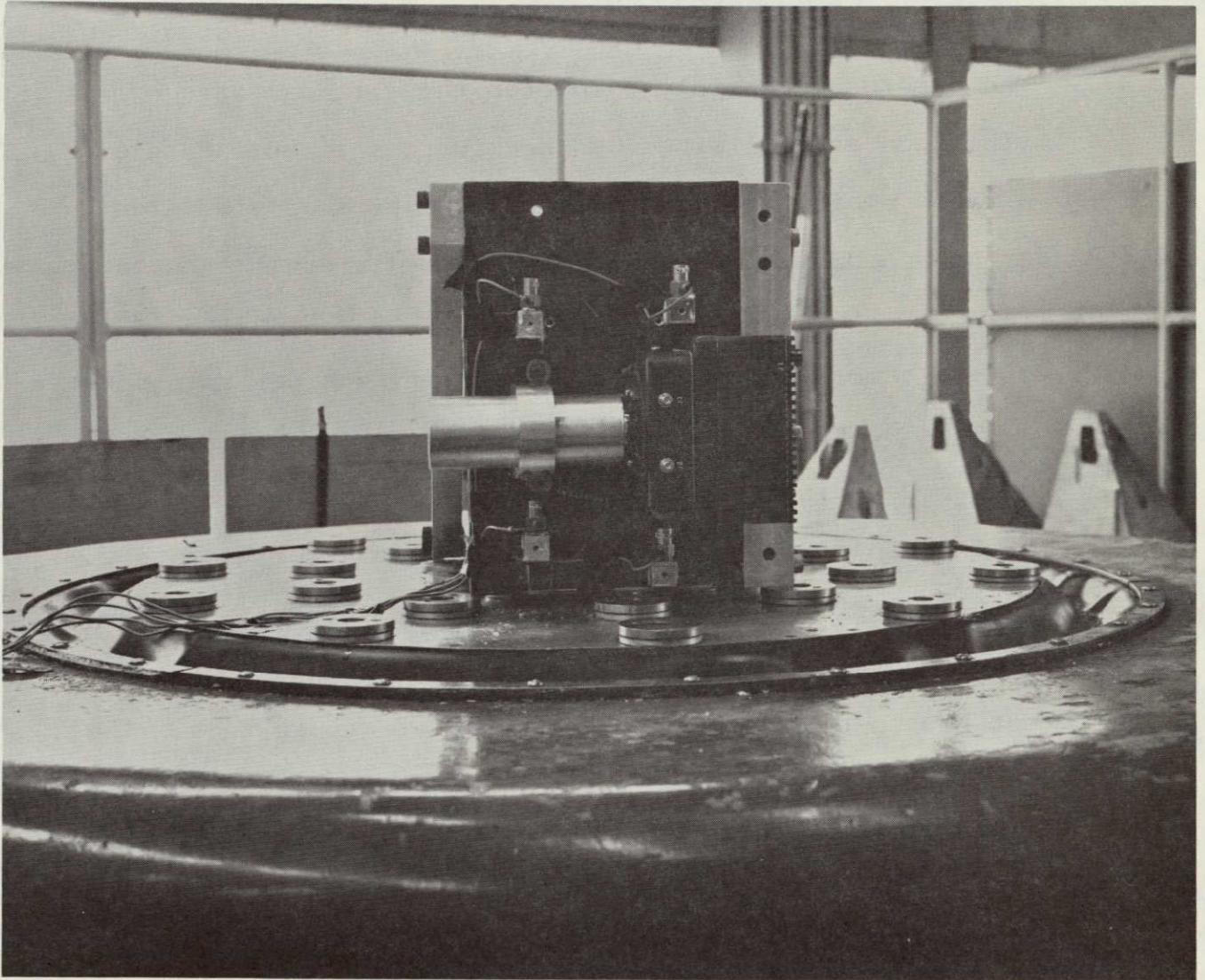


FIGURE 1. VIBRATION TEST SETUP

2.4 TEST RESULTS

- 2.4.1 The camera successfully completed the vertical axis of vibration as determined by checking camera operation on a video monitor before and after the axis of vibration.
- 2.4.2 At the completion of the second axis (lateral), the camera failed to image when initially turned on. Upon inspection of the camera and electrical tests, it was determined that:
- a) The 504 KHz crystal was defective.
 - b) Two capacitors on the $\pm 12\text{VDC}$ to DC converter broke off.
 - c) One capacitor on the $+5\text{VDC}$ to DC converter broke off.
- 2.4.3 Upon inspection of the camera DC-DC converters, it was observed that the filter capacitors mentioned above had not been securely attached to the DC-DC converters. The capacitors had broken because they were only secured to the DC-DC converters by means of their leads.
- 2.4.4 The repair of the camera consisted of coating the capacitors and the area where they were attached to the DC-DC converters with conformal coating. The crystal apparently was more sensitive to vibration than expected and was replaced with a more reliable and smaller ceramic resonator.
- 2.4.5 The camera was then reinspected for proper workmanship and subjected to the third axis of vibration (longitudinal).
- 2.4.6 Upon completion of the third axis, the camera was energized

and failed to image. An inspection revealed the following:

- a) Three capacitors from the video processor board had broken off during vibration.
- b) One resistor from the video processor board had broken off during vibration.
- c) The "H" clock potentiometer cracked.
- d) The wiring harness from the logic board to the array board frayed.

2.4.7 When the camera was inspected, it was noted that a capacitor on the video processor board had been mounted incorrectly. The remaining parts on the video processor board that had broken off did not have sufficient conformal coating to hold them securely to the board. These parts were changed and the new parts were remounted and recoated on the video board.

2.4.8 In order to prevent the wiring harness from the logic board to the array board from becoming frayed, the opening that this wire bundle fed through had its edges made smoother and a length of tubing was placed on the wires where they were frayed before to help prevent contact between the wire insulation and the slot in the array support housing through which they feed.

2.4.9 The "H" clock potentiometer that had cracked was still functional. It is extremely unlikely that vibration caused its mechanical failure, but rather that the part

was inadvertantly damaged during assembly of the camera. The only corrective action in this case was the replacement of the potentiometer and more careful attention to assembling the camera.

2.4.10 An operational performance test in accordance with Section III of QA Report 1615 Rev. B was then conducted. The results were recorded on the data sheets following this page.

2.4.11 Although a significant number of component failures occurred during the vibration test, these failures were found to be due to workmanship-related defects in small parts support which were not found and corrected prior to testing. No failures of critical components such as the CCD Sensor/TE cooler package or other major structural parts of the camera occurred.

NASA/JSC ADVANCED DESIGN SOLID STATE
TELEVISION CAMERA SYSTEM
PERFORMANCE TEST DATA SHEET

Sheet 1 of 2

3.0 Camera Serial Number 6186-001

Lens Serial Number 13-260-041

Environmental Preconditioning Post - Vibration

4.2 Light Level Calibration

b) Test pattern highlight brightness 502 f1

c) "f" number for one stop below saturation: f 5.6

d) $I_H = \frac{B \times 0.8}{4f^2 \times 100} = \underline{.032}$ fc (1 stop below saturation)

e) $f = \left(\frac{B \times 0.8}{4 \times 5 \times 10^{-2} \times 10^2} \right)^{1/2}$

B = 400 ft. lam.

f = f4

4.3 Resolution *

Horizontal Resolution 275 TVL/PH ≥ 200 FCI 976 Accept
 ≤ 200 Reject

Vertical Resolution 350 TVL/PH ≥ 342 FCI 976 Accept
 342 Reject

4.4 Dark Current non-Uniformity* (.025v)

Video output non-uniformity ≤ 10 IRE units (71.4mV) FCI 976 Accept

Video output non-uniformity ≥ 10 IRE units (71.4mV) Reject

4.5 Signal-to-Noise Ratio

Peak-to-peak highlight video signal V_{p-p} .640v

* Record observed values

Peak-to-peak temporal noise variations N_{p-p} .020✓
 $SNR = 20 \log (6 V_{p-p} / N_{p-p})$
 $=$ 44.96 dB ≤ 40 dB ✓ FCI 976 Accept
 > 40 dB _____ Reject

4.6 Automatic Light Control (ALC)

ALC voltage from step (a) 3.05✓
 ALC voltage within $\pm 5\%$ of step (a) FCI Accept
 ALC voltage not within $\pm 5\%$ of step (a) 976 Reject

4.7 Output Video Format

Composite video polarity, black negative ✓ FCI 976 Accept
 black negative _____ Reject
 Blanked picture signal with setup, $V_{pp} =$.640 V;
 0.614V to 0.814V ✓ FCI 976 Accept
 < 0.614 V to > 0.814 V _____ Reject
 Sync signal (from 0VDC Ref.) $V_s =$.280 V
 0.236V to 0.336V ✓ FCI 976 Accept
 < 0.236 V to > 0.336 V _____ Reject
 Setup, blanking level to ref. black level 7 IRE units*
 *Passes spec until 25% average picture level
 7.0 to 8.0 IRE units ✓ FCI 976 Accept
 < 7.0 to > 8.0 IRE units _____ Reject
 Sync signal waveform per EIA RS-170 ✓ FCI 976 Accept
 _____ Reject

4.8 Power Supply

Power supply input voltage ✓ FCI 976 28VDC
 Camera system operates at 24VDC and 32VDC ✓ FCI 976 Accept
 Camera system does not operate at 24VDC and 32 VDC ✓ _____ Reject
 → Camera system input current ≤ 890 mA ✓ FCI 976 Accept
 → Camera system input current > 890 mA _____ Reject

Indicates
 → revision 11/78

Test conducted by E. Misura
 Test witnessed by K. Wilson FCI 976
 Date 10-11-78

VERTICAL AXIS 10/3/78

POST TEST

RMS LEVEL = 18.17 G'S

G SQR/HZ

ELAPSED TIME = 1524 SECS

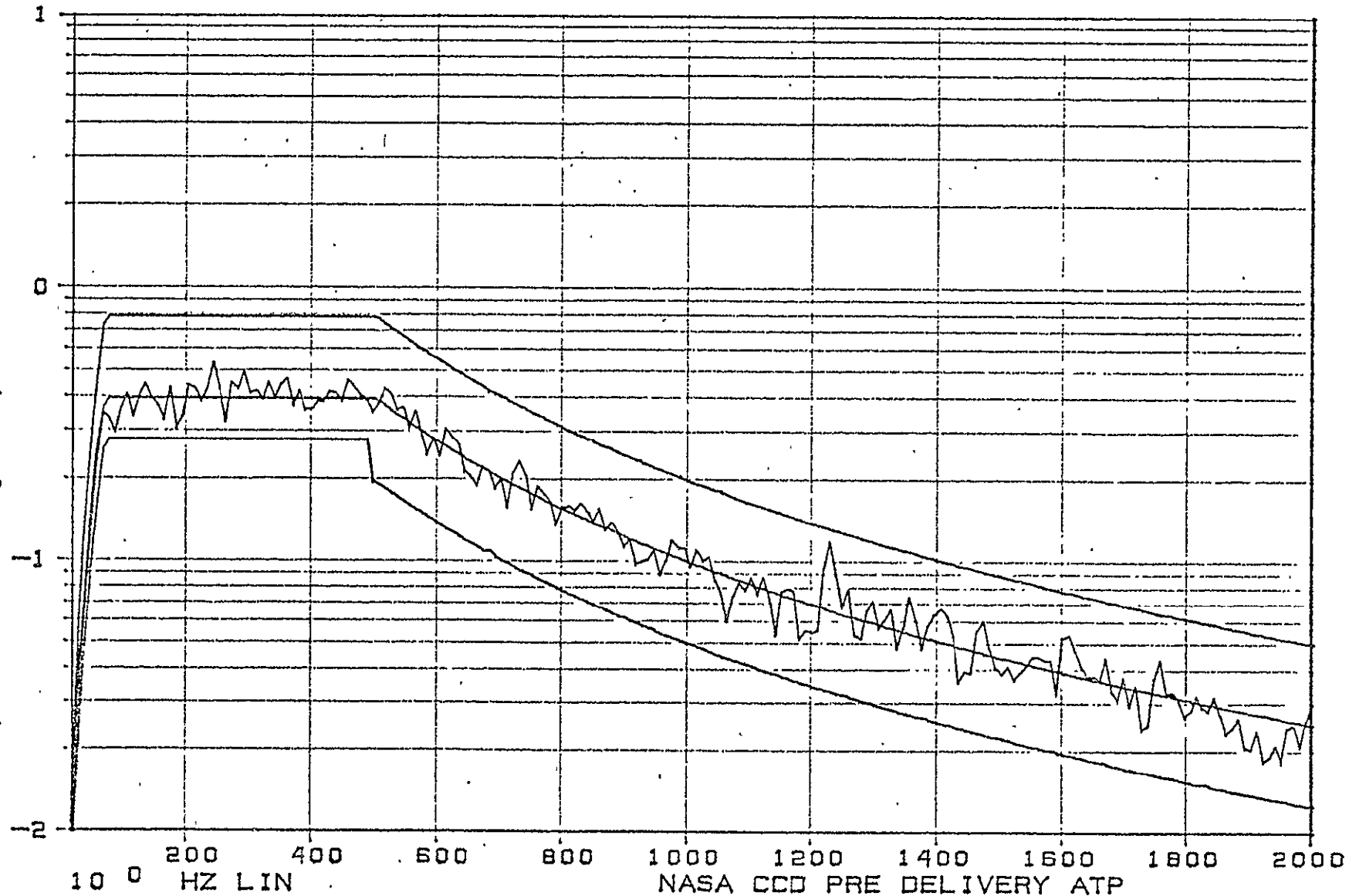
DELTA F = 9.766

DOF = 61

AWF = 16

10N

Figure 2



LATERAL AXIS 10/4/78

POST TEST

RMS LEVEL = 18.29 G'S

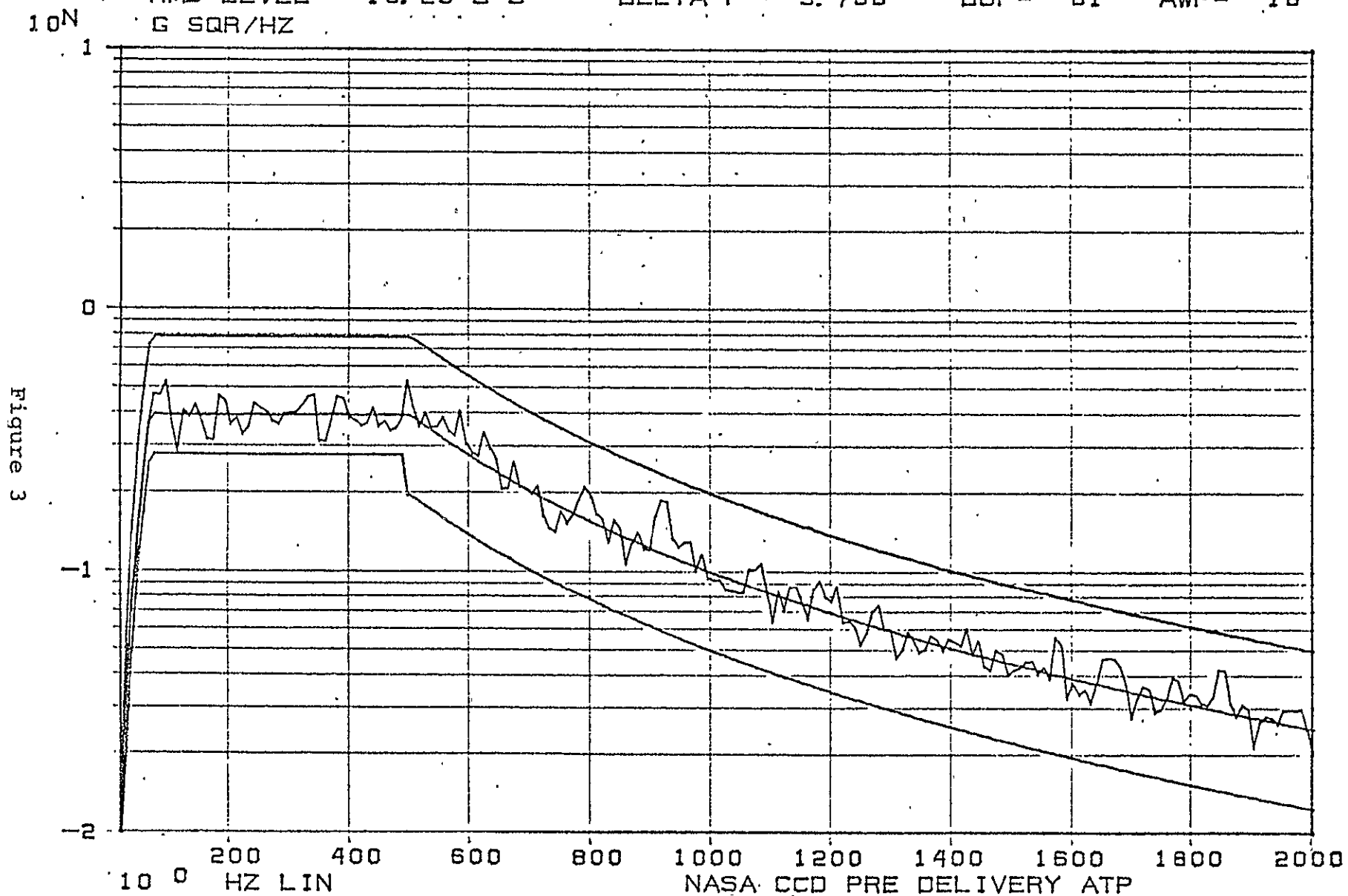
G SQR/HZ

ELAPSED TIME = 2041 SECS Δ

DELTA F = 9.766

DOF = 61

AWF = 16



LONGITUDINAL AXIS 10/6/78

POST TEST

RMS LEVEL = 18.25 G'S

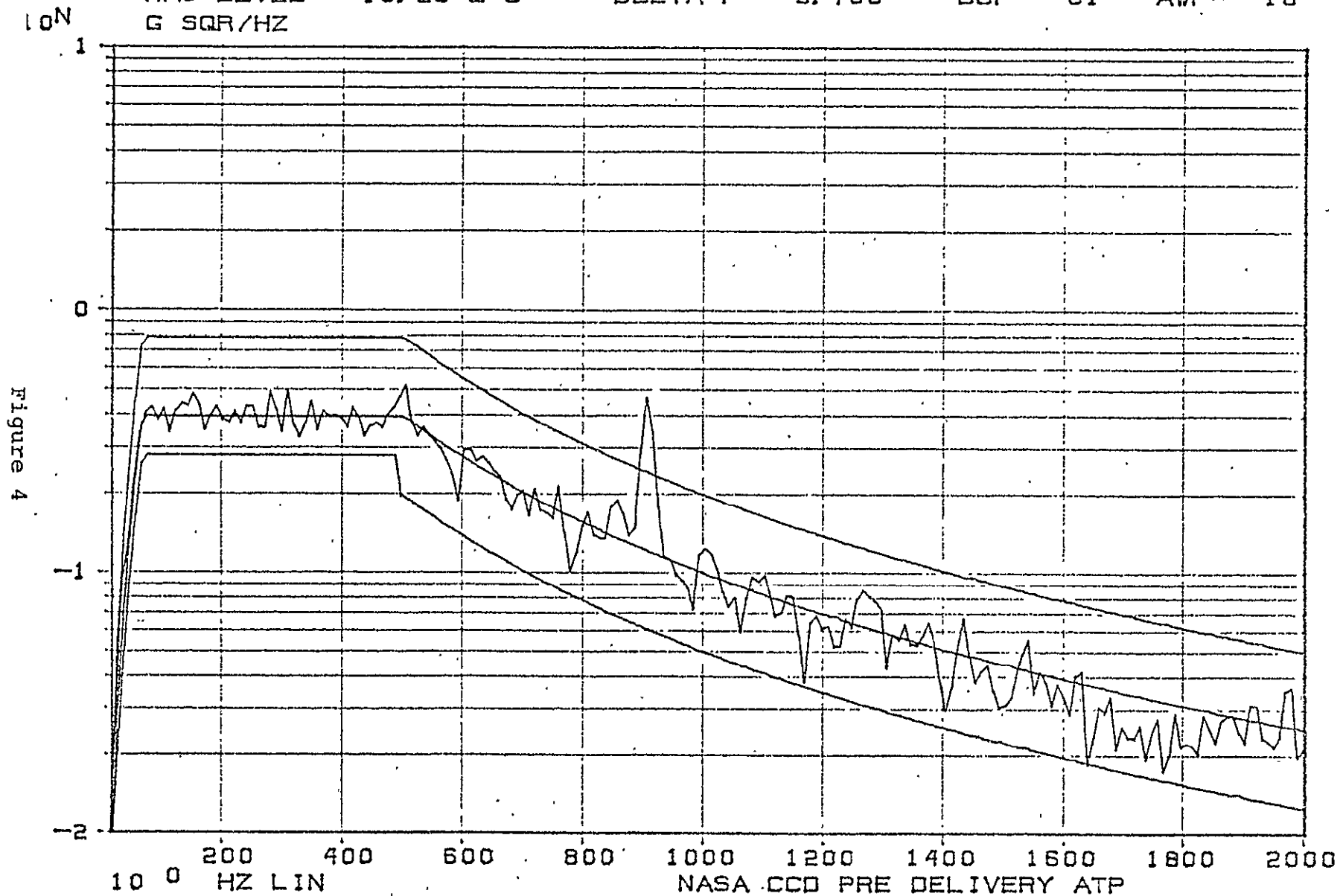
G SQR/HZ

ELAPSED TIME = 2053 SECS AT -3.00 DB

DELTA F = 9.766

DOF = 61

AWF = 16



3.0 SHOCK TEST

3.1 TEST EQUIPMENT (or equivalent)

Vibration System
MB Electronics
Model: C210

Vibration Control System
Hewlett Packard
Model: 5425A

Accelerometer
Endevco
Type 2215

Shock Amplifier
Endevco
Model: 2740B

3.2 TEST SETUP

The camera system was mounted on a vibration fixture which was secured to an electrodynamic vibration exciter. For this test, the zoom lens was replaced with a mass model simulating the mass distribution and mounting features of the zoom lens assembly. An accelerometer was mounted on the fixture adjacent to the fixture/specimen interface to monitor the shock input level. The system was de-energized during the shock exposure period.

3.3 TEST PROCEDURE

The camera system was subjected to a terminal peak saw-tooth shock pulse of 11 milliseconds duration and 20g peak amplitude, in each of six directions along the system's three orthogonal axes. Calibration and post

test plots of the shock pulse are shown in Figures 5 through 11.

At the conclusion of the exposure period, the camera was examined for evidence of damage and subjected to a complete performance check to verify proper operation.

3.4 TEST RESULTS

There was no sign of mechanical damage or degradation as a result of the Shock Test. An operation performance test in accordance with Section III of QA Report 1615 Rev. B was conducted at the conclusion of the shock test. The results were recorded on the data sheets following this page.

NASA/JSC ADVANCED DESIGN SOLID STATE
TELEVISION CAMERA SYSTEM
PERFORMANCE TEST DATA SHEET

Sheet 1 of 2

3.0 Camera Serial Number 6186-001
Lens Serial Number 13-260-041
Environmental Preconditioning Post Shock

4.2 Light Level Calibration

- b) Test pattern highlight brightness 502 fl
- c) "f" number for one stop below saturation: f 5.6
- d) $I_H = \frac{B \times 0.8}{4f^2 \times 100} = \underline{.037}$ fc (1 stop below saturation)
- e) $f = \left(\frac{B \times 0.8}{4 \times 5 \times 10^{-2} \times 10^2} \right)^{1/2}$
B = 400 ft. lam.
f = f4

4.3 Resolution

Horizontal Resolution 275 TVL/PH ≥ 200 FCI 976 Accept
 ≤ 200 _____ Reject
Vertical Resolution 350 TVL/PH ≥ 342 FCI 976 Accept
 ≤ 342 _____ Reject

4.4 Dark Current non-Uniformity* (.030v)

Video output non-uniformity ≤ 10 IRE units (71.4mV) FCI 976 Accept
Video output non-uniformity ≥ 10 IRE units (71.4mV) _____ Reject

4.5 Signal-to-Noise Ratio

Peak-to-peak highlight video signal V_{p-p} .700v

* Record observed values

Peak-to-peak temporal noise variations N_{p-p} .020 ✓

SNR = 20 log (6 V_{p-p}/N_{p-p})

= 45.39 dB ≤ 40dB ✓ FCI 976 Accept
 > 40dB _____ Reject

4.6 Automatic Light Control (ALC)

ALC voltage from step (a) 1.22 ✓

ALC voltage within ±5% of step (a) ✓ FCI 976 Accept

ALC voltage not within ±5% of step (a) _____ Reject

4.7 Output Video Format

Composite video polarity, black negative ✓ FCI 976 Accept
 black negative _____ Reject

Blanked picture signal with setup, V_{pp} = .700 V;

0.614V to 0.814V ✓ FCI 976 Accept

<0.614V to >0.814V _____ Reject

Sync signal (from 0VDC Ref.) V_s = .285 V

0.236V to 0.336V ✓ FCI 976 Accept

<0.236V to >0.336V _____ Reject

Setup, blanking level to ref. black level 7 IRE units*

*Passes spec until 25% average picture level

7.0 to 8.0 IRE units ✓ FCI 976 Accept

<7.0 to >8.0 IRE units _____ Rejec

Sync signal waveform per EIA RS-170 ✓ FCI 976 Accept

_____ Reject

4.8 Power Supply

Power supply input voltage ✓ FCI 976 28VDC

Camera system operates at 24VDC and 32VDC ✓ FCI 976 Accept

Camera system does not operate at 24VDC and 32 VDC ✓ _____ Reject

Camera system input current ≤ 890mA ✓ FCI 976 Accept

Camera system input current > 890mA _____ Reject

Indicates

revision 11/78

Test conducted by G. Miciura

Test witnessed by K. Allen FCI 976

date 10-11-78

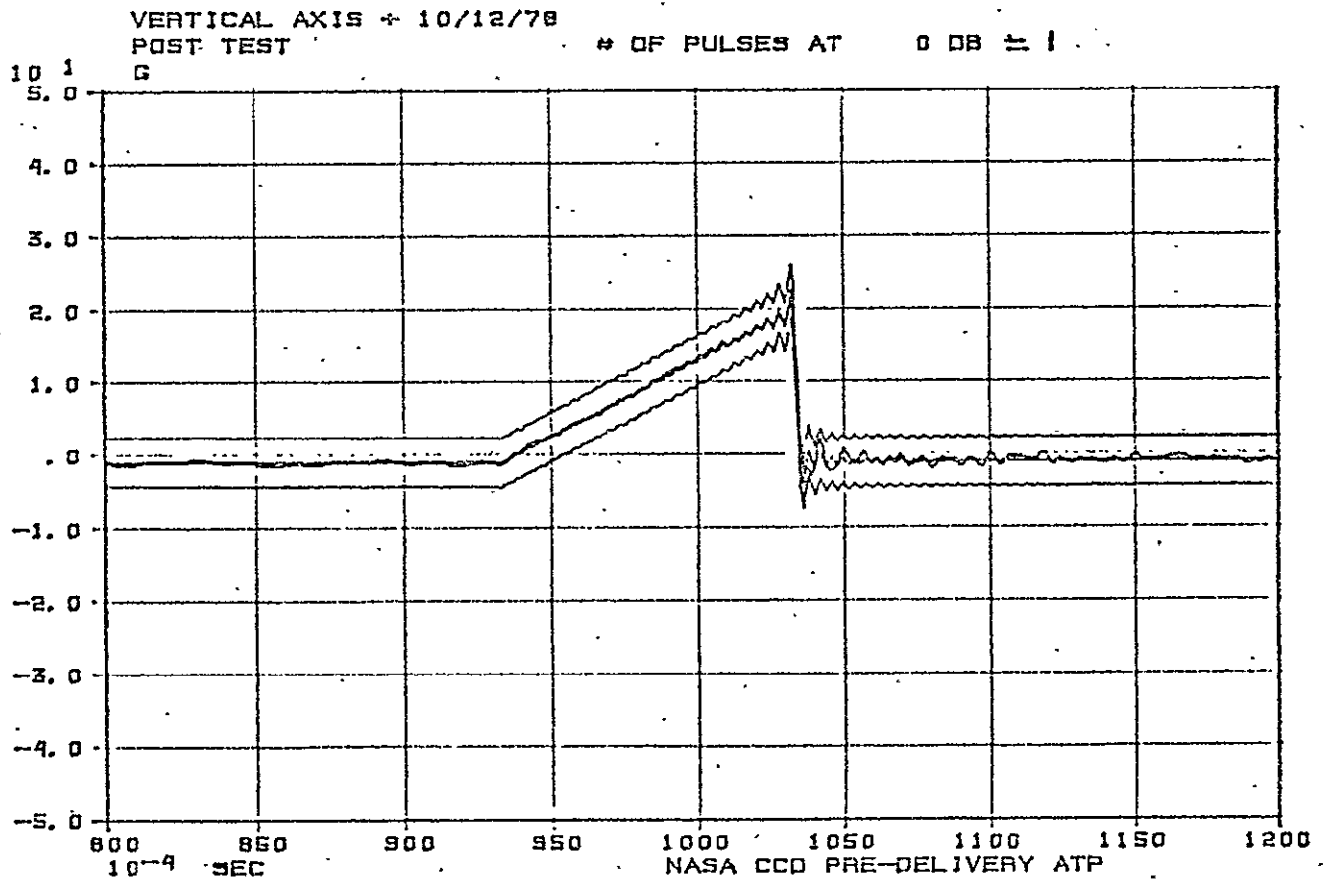
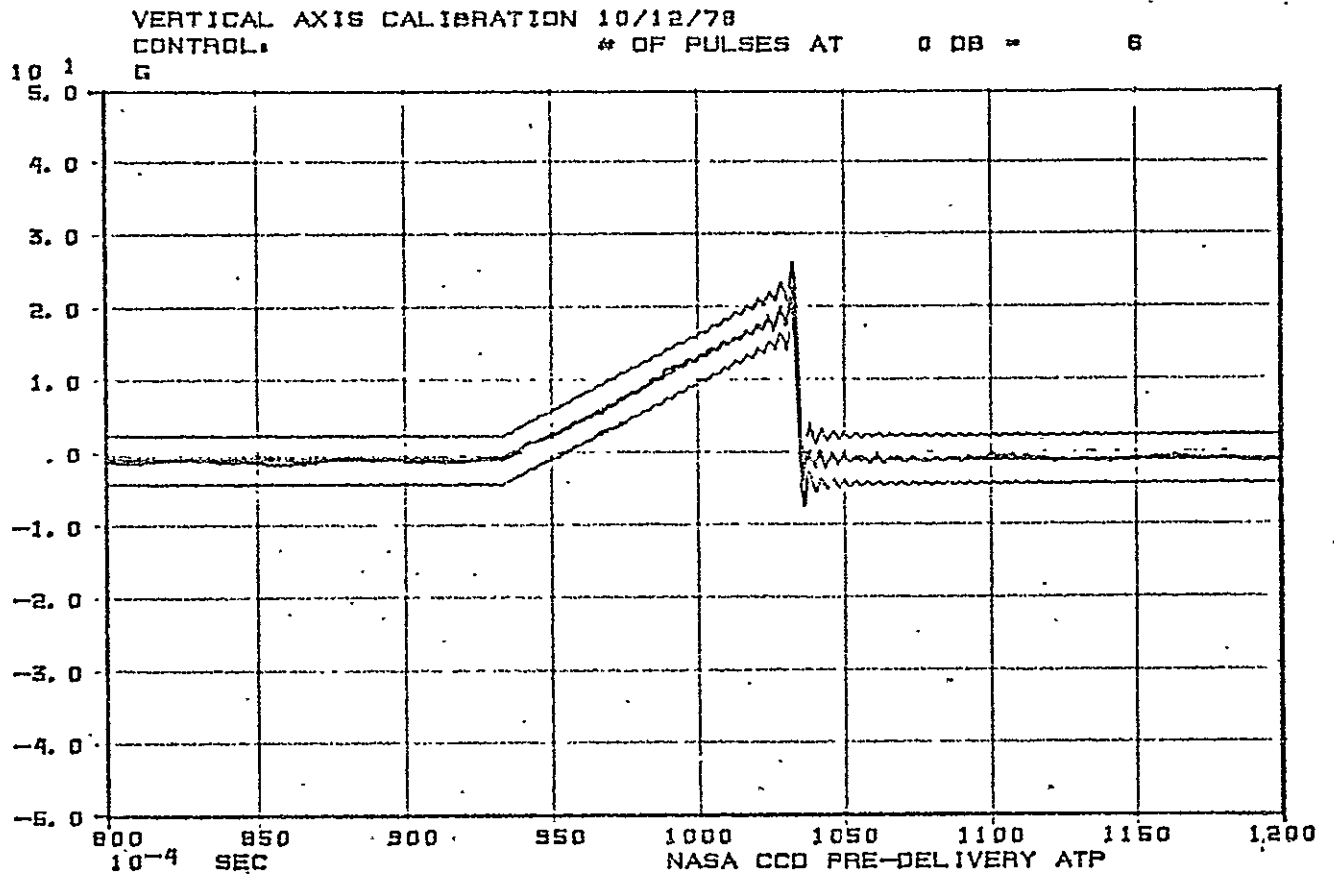
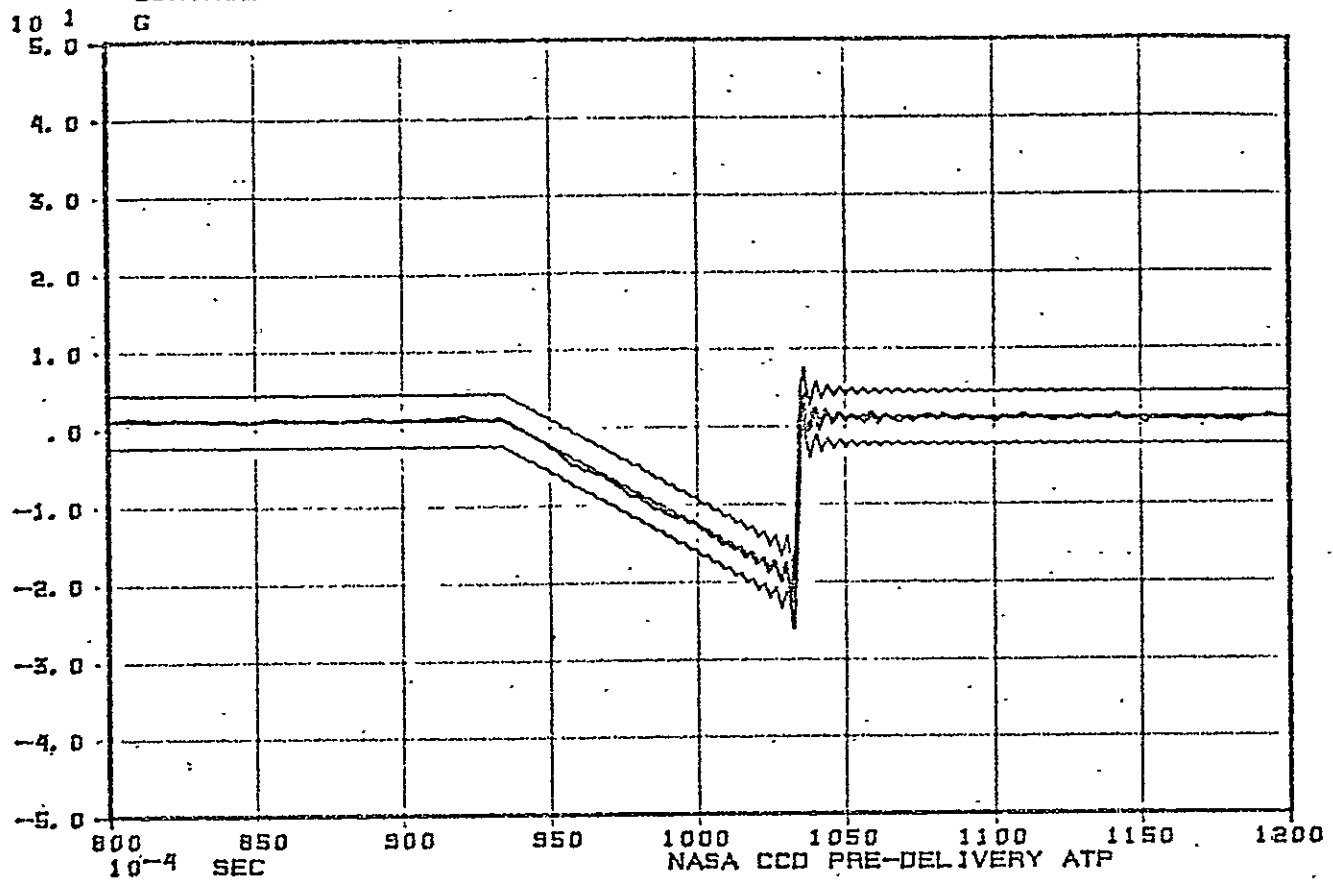


Figure 5

VERTICAL AXIS CALIBRATION 10/12/78

CONTROL:

OF PULSES AT 0 DB = 6



VERTICAL AXIS - 10/12/78

POST TEST

OF PULSES AT 0 DB = 1

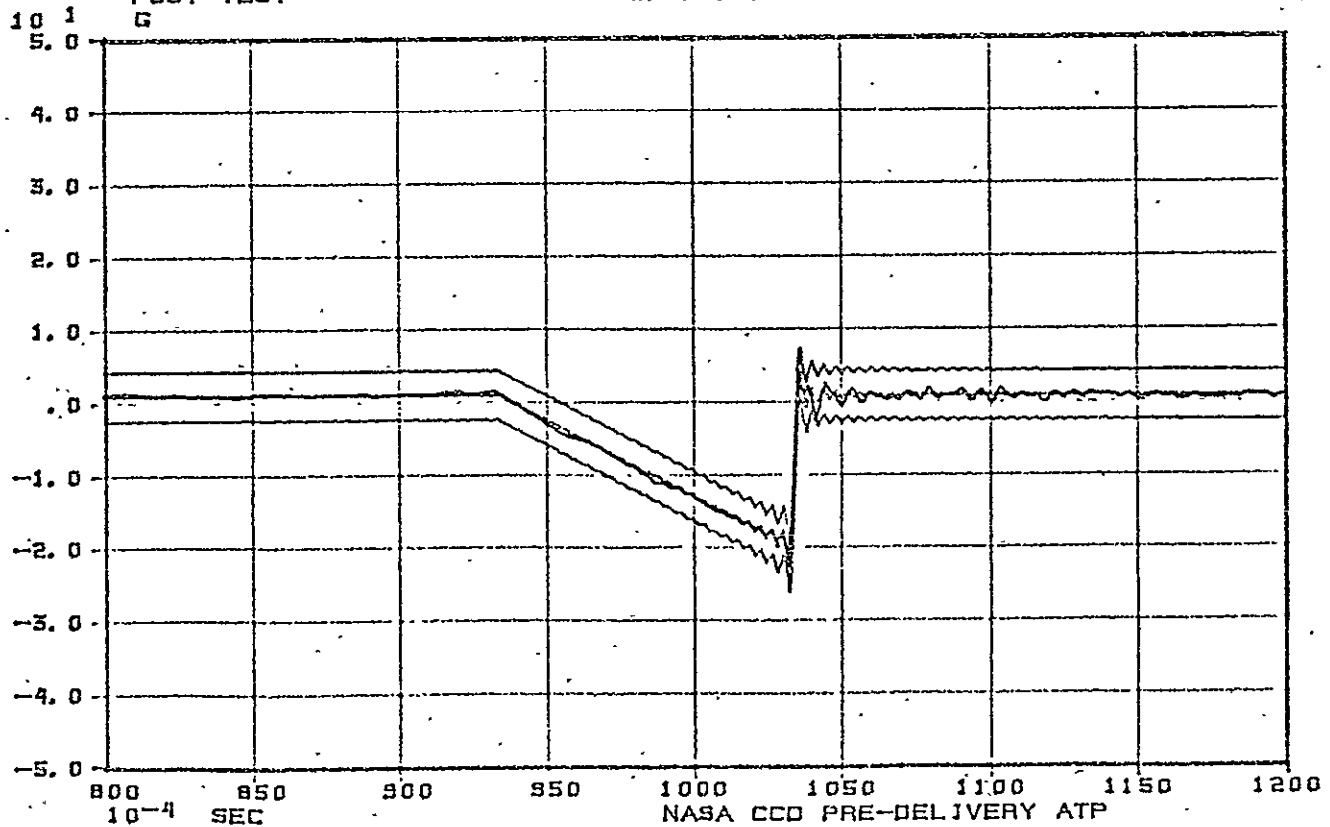


Figure 6

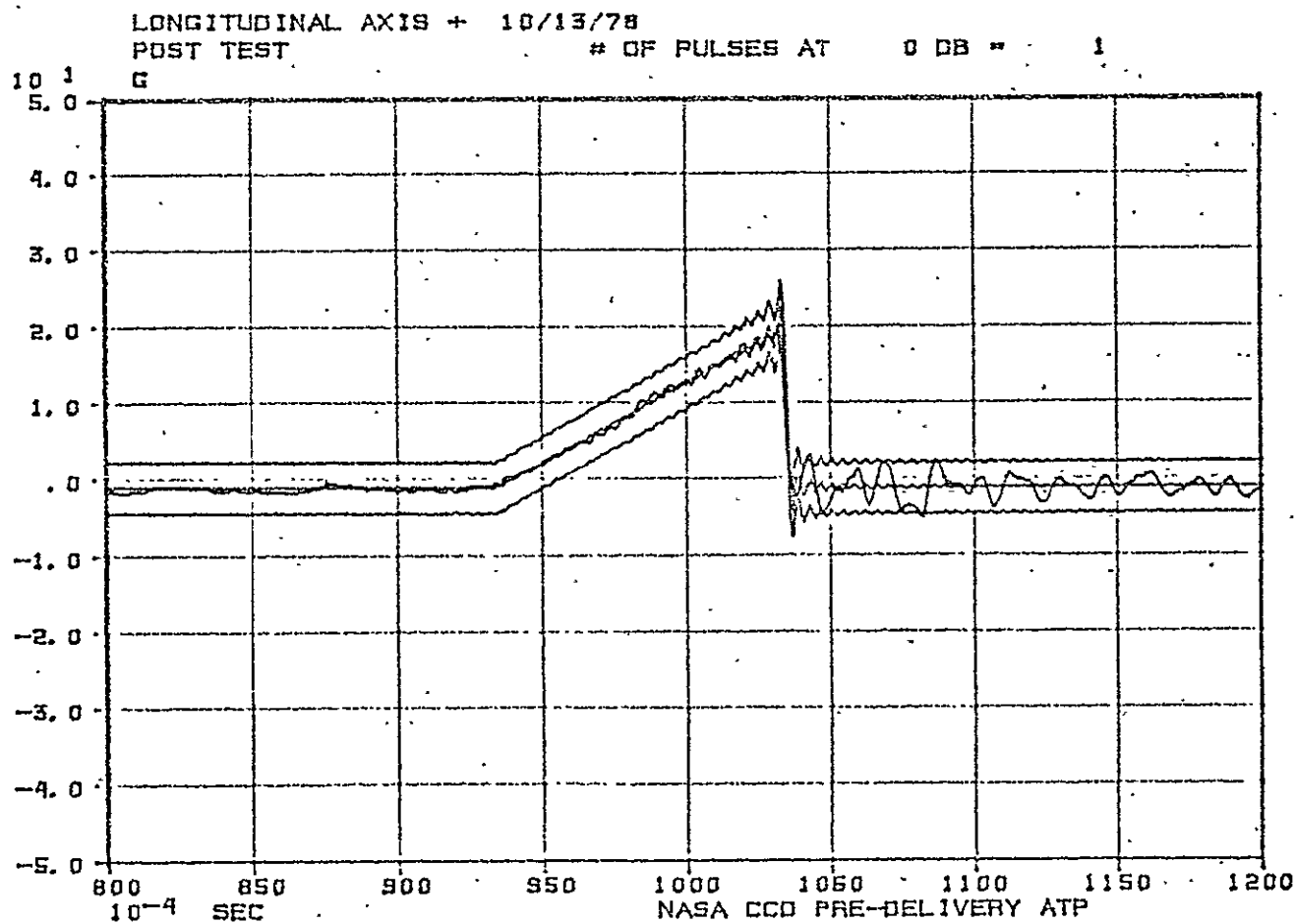
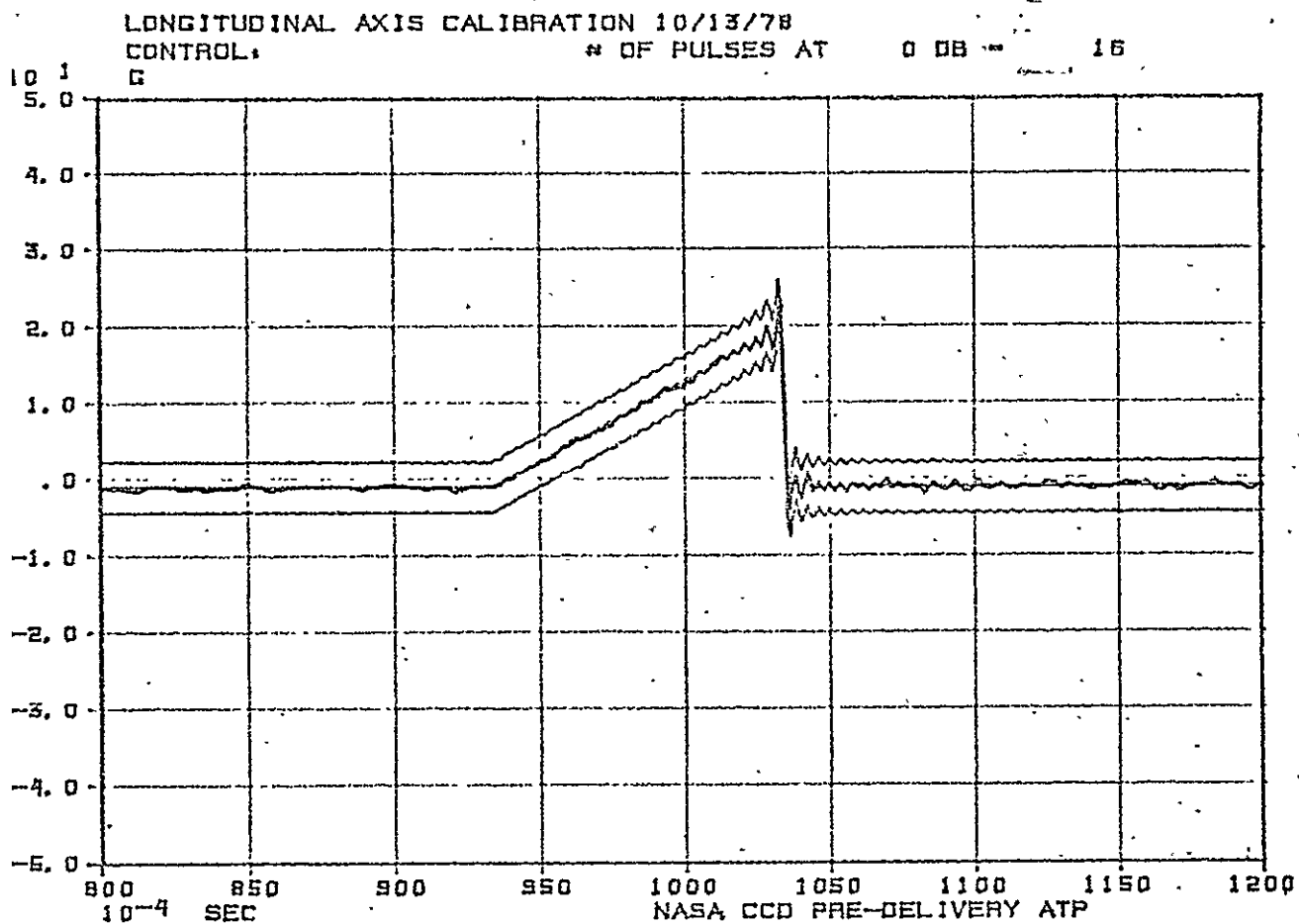


Figure 7

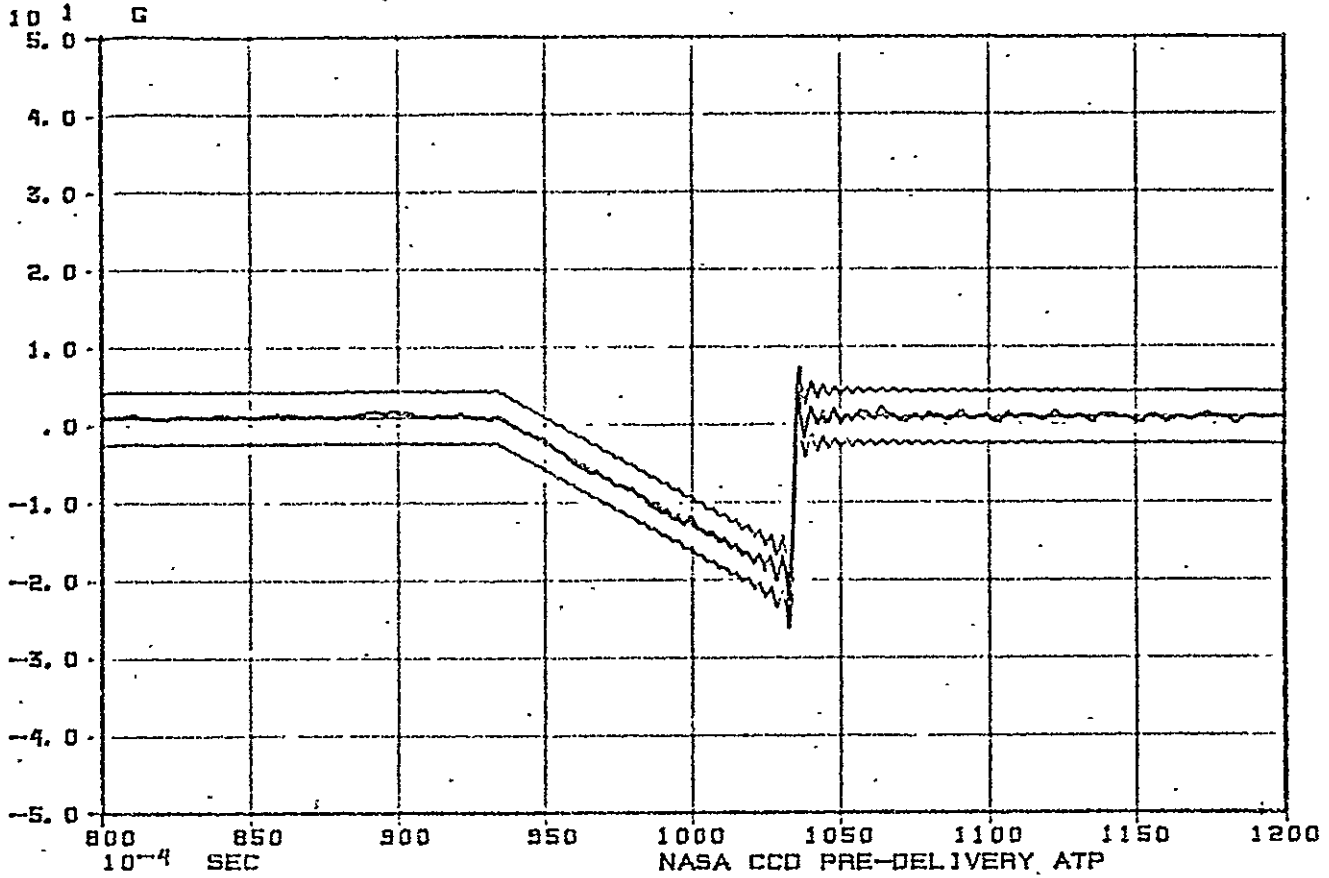
LONGITUDINAL AXIS - CALIBRATION 10/13/78

CONTROL:

OF PULSES AT

0 DB =

10



LONGITUDINAL AXIS - 10/13/78

POST TEST

OF PULSES AT

0 DB =

1

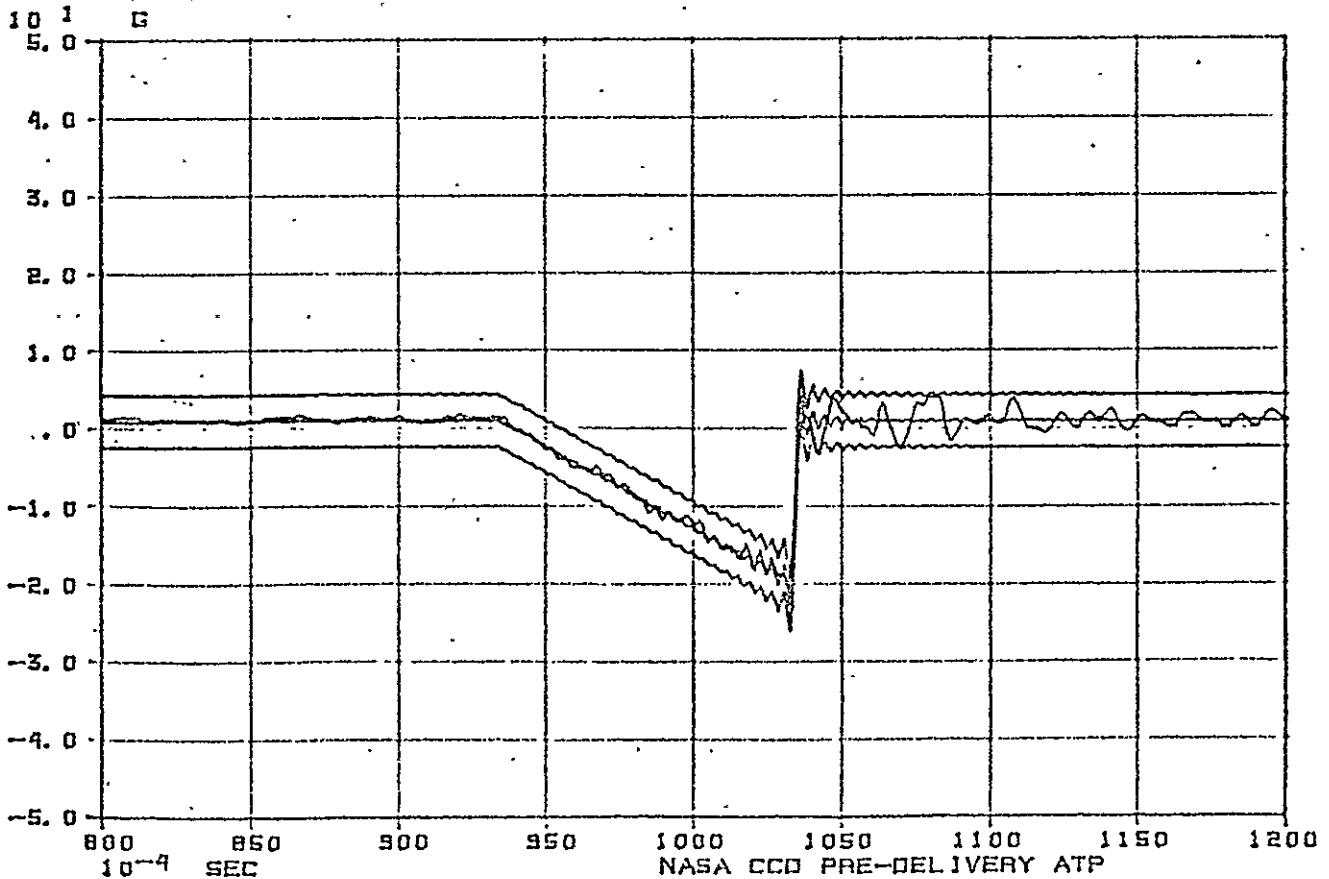


Figure 8

LATERAL AXIS CALIBRATION 10/12/78

CONTROL:

OF PULSES AT

0 DB

8

10 1

5.0

4.0

3.0

2.0

1.0

0.0

-1.0

-2.0

-3.0

-4.0

-5.0

800

850

900

950

1000

1050

1100

1150

1200

10⁻⁴ SEC

NASA CCD PRE-DELIVERY ATP

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LATERAL AXIS + 10/12/78

POST TEST

OF PULSES AT

0 DB

10 1

5.0

4.0

3.0

2.0

1.0

0.0

-1.0

-2.0

-3.0

-4.0

-5.0

800

850

900

950

1000

1050

1100

1150

1200

10⁻⁴ SEC

NASA CCD PRE-DELIVERY ATP

Figure 2

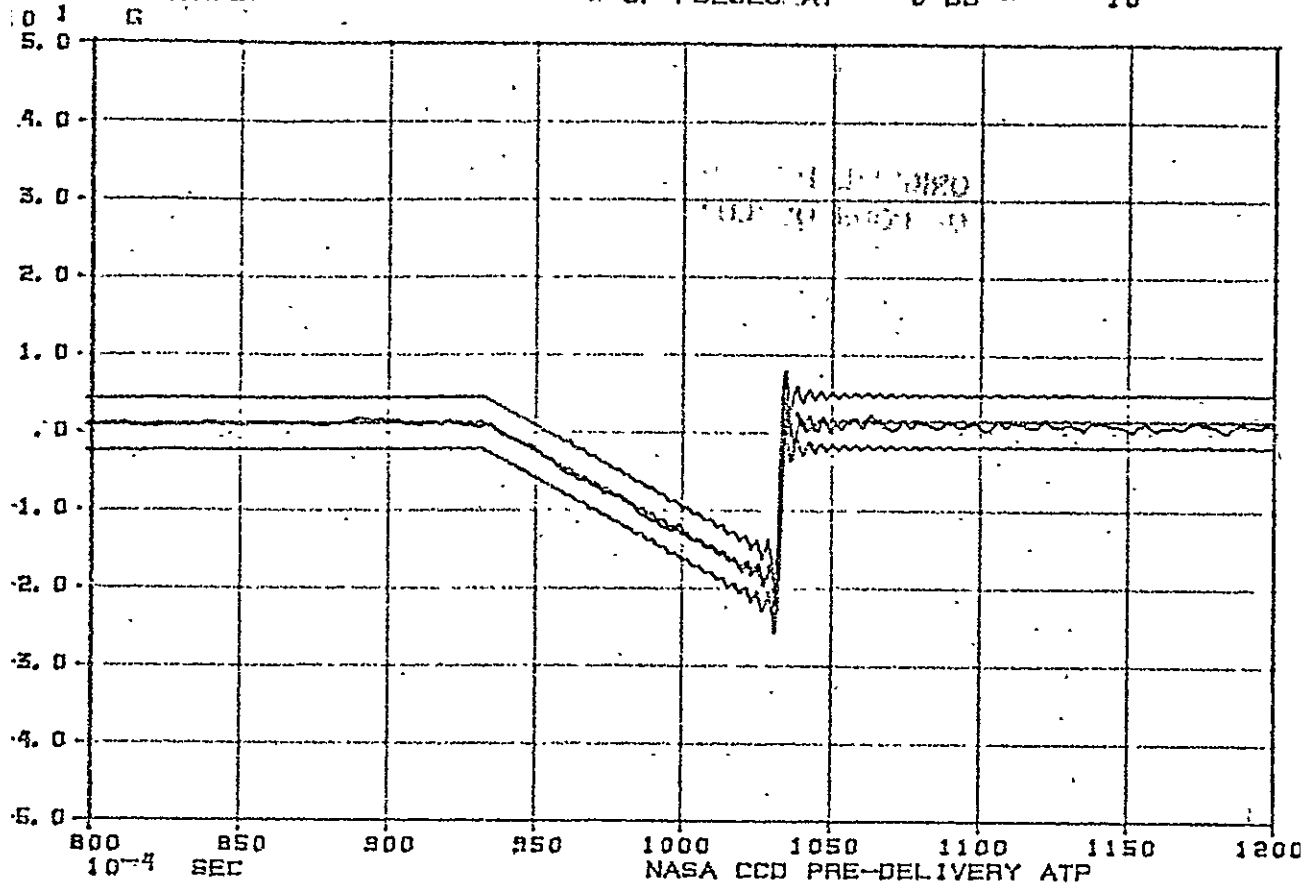
LATERAL AXIS CALIBRATION 10/13/78

CONTROL:

OF PULSES AT

0 DB

10



LATERAL AXIS - 10/13/78

POST TEST

OF PULSES AT

0 DB

1

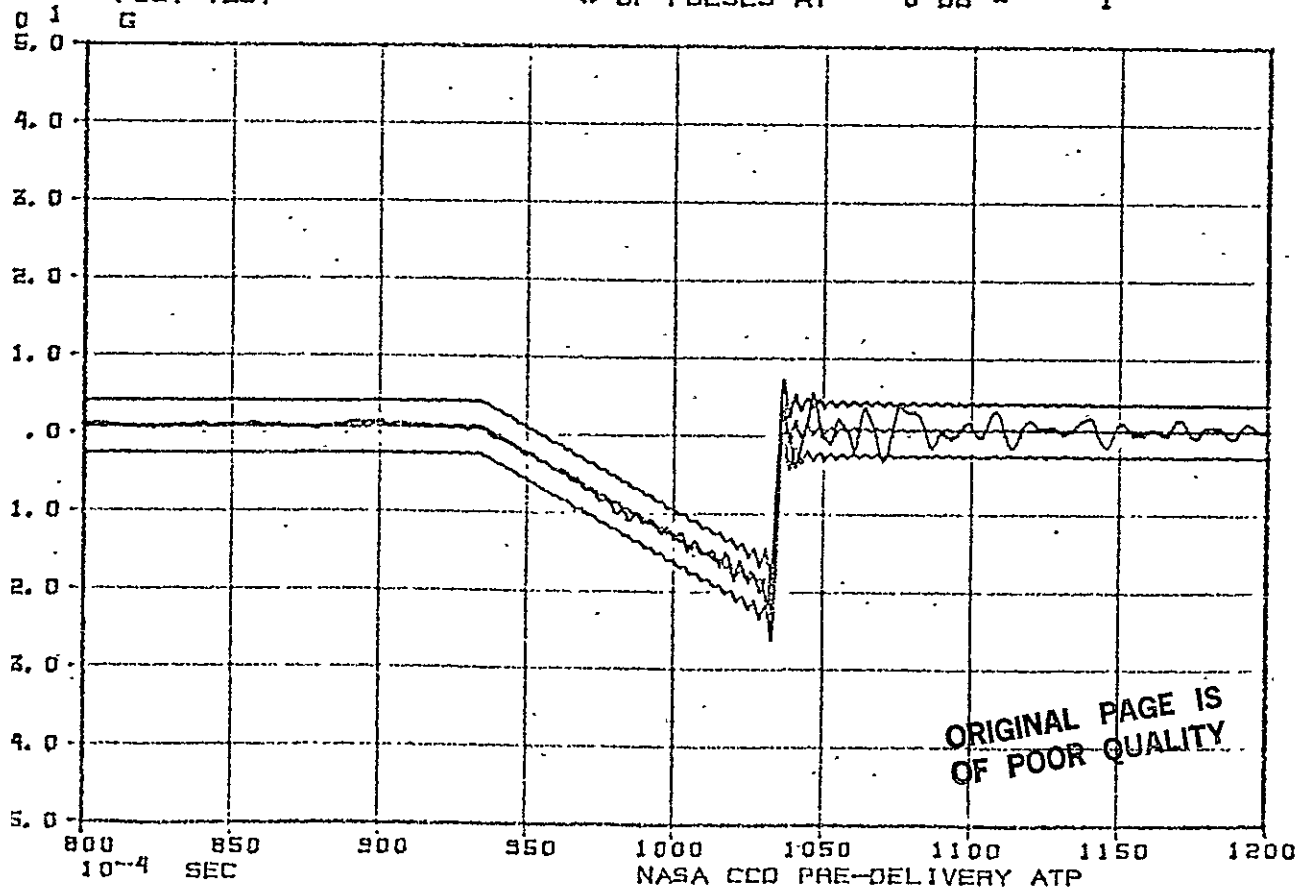
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Figure 10

4.0 ACCELERATION

4.1 TEST EQUIPMENT (or equivalent)

Accelerator
Genesco
Model: A1030

Counter
Hewlett-Packard
Model: 5223L

4.2 TEST SETUP

The camera system was secured to a centrifuge with a rotating arm of sufficient length to maintain the acceleration gradient within $+5g$. For this test, the zoom lens was replaced with a mass model simulating the mass distribution and mounting features of the zoom lens assembly. The camera system was de-energized during the acceleration test. A photograph of the test setup is included as Figure 11.

4.3 TEST PROCEDURE

The camera system was subjected to a five minute exposure of an acceleration level of $5.0g$'s in each direction along the system's three orthogonal axes. At the conclusion of the test period, the camera system was examined for evidence of damage and subjected to a complete performance check to verify proper operation.

4.4 TEST RESULTS

There was no sign of mechanical damage or degradation as a result of the Acceleration Test. An operation perfor-

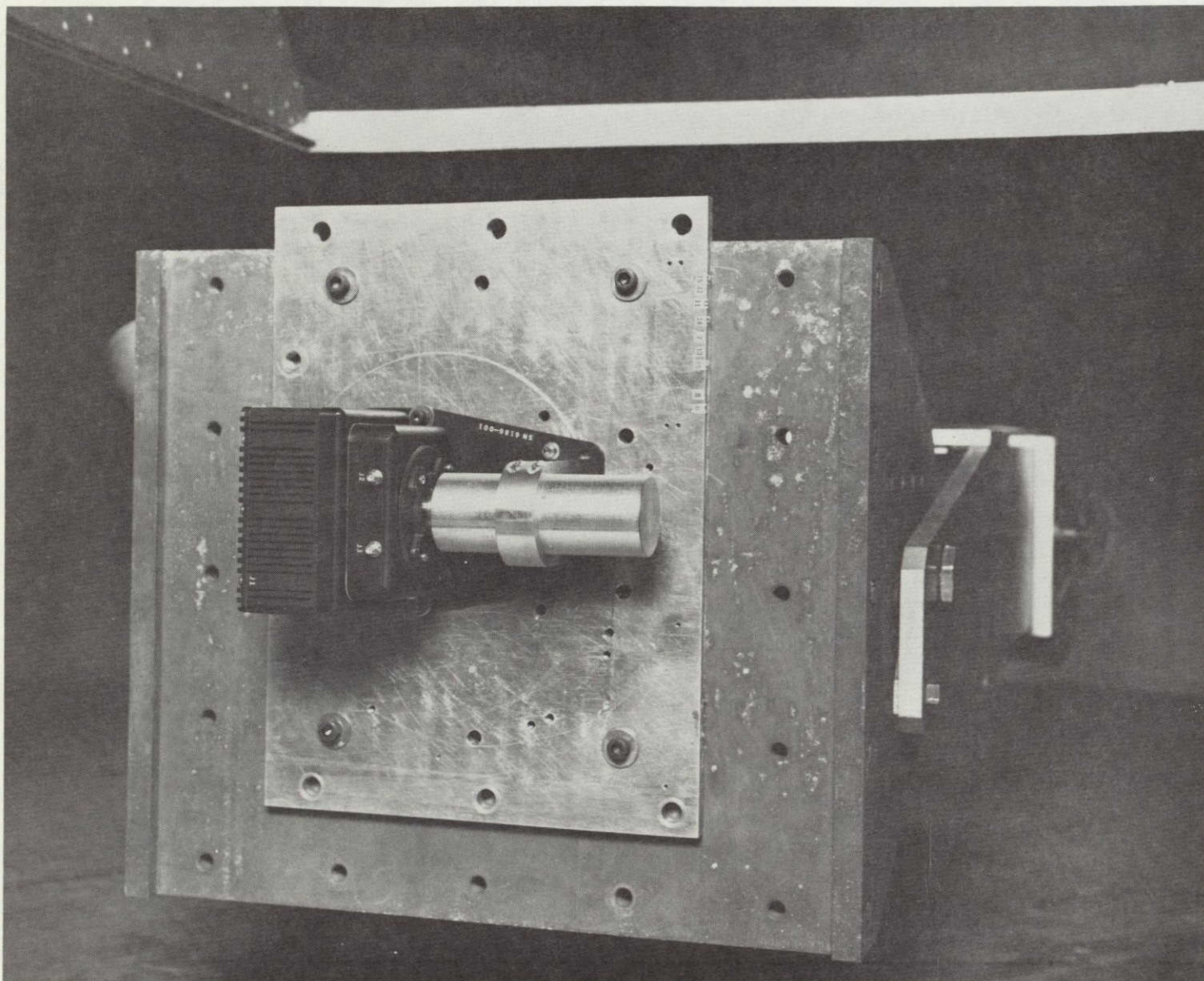


FIGURE 11. ACCELERATION TEST SETUP

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mance test in accordance with Section III of QA Report No. 1615 Rev. B was conducted at the conclusion of the acceleration test. The results were recorded on the data sheets following this page.

NASA/JSC ADVANCED DESIGN SOLID STATE
TELEVISION CAMERA SYSTEM
PERFORMANCE TEST DATA SHEET

Sheet 1 of 2

3.0 Camera Serial Number 6186-001

Lens Serial Number 13-260-041

Environmental Preconditioning Post Accel.

4.2 Light Level Calibration

b) Test pattern highlight brightness 502 f1

c) "f" number for one stop below saturation: f 5.6

d) $I_H = \frac{B \times 0.8}{4f^2 \times 100} = \underline{.032}$ fc (1 stop below saturation)

e) $f = \left(\frac{B \times 0.8}{4 \times 5 \times 10^{-2} \times 10^2} \right)^{1/2}$ ft.

B = 400 ft. lam.

f = f4

4.3 Resolution *

Horizontal Resolution 275 TVL/PH ≥ 200 ✓FCI 976 Accept
 ≤ 200 _____ Reject

Vertical Resolution 350 TVL/PH ≥ 342 ✓FCI 976 Accept
 ≤ 342 _____ Reject

4.4 Dark Current non-Uniformity* (.040v)

Video output non-uniformity ≤ 10 IRE units (71.4mV) ✓FCI 976 Accept

Video output non-uniformity ≥ 10 IRE units (71.4mV) _____ Reject

4.5 Signal-to-Noise Ratio

Peak-to-peak highlight video signal V_{p-p} .700 ✓

* Record observed values

Peak-to-peak temporal noise variations N_{p-p} .020 v

$$SNR = 20 \log (6 V_{p-p} / N_{p-p})$$

$$= \underline{45.67 \text{ dB}}$$

$\leq 40 \text{ dB}$ ✓ FCI 976 Accept

$> 40 \text{ dB}$ _____ Reject

4.6 Automatic Light Control (ALC)

ALC voltage from step (a) 2.4 ✓

ALC voltage within $\pm 5\%$ of step (a) FCI Accept

ALC voltage not within $\pm 5\%$ of step (a) 976 Reject

4.7 Output Video Format

Composite video polarity, black negative ✓ FCI 976 Accept

black negative _____ Reject

Blanked picture signal with setup, $V_{pp} = \underline{.700 \text{ V}}$

0.614 V to 0.814 V ✓ FCI 976 Accept

$< 0.614 \text{ V}$ to $> 0.814 \text{ V}$ _____ Reject

Sync signal (from 0VDC Ref.) $V_s = \underline{.285 \text{ V}}$

0.236 V to 0.336 V ✓ FCI 976 Accept

$< 0.236 \text{ V}$ to $> 0.336 \text{ V}$ _____ Reject

Setup, blanking level to ref. black level 7 IRE units*

*Passes spec until 25% average picture level

7.0 to 8.0 IRE units ✓ FCI 976 Accept

< 7.0 to > 8.0 IRE units _____ Reject

Sync signal waveform per EIA RS-170 ✓ FCI 976 Accept

_____ Reject

4.8 Power Supply

Power supply input voltage ✓ FCI 976 28VDC

Camera system operates at 24VDC and 32VDC ✓ FCI 976 Accept

Camera system does not operate at 24VDC and 32 VDC ✓ Reject

→ Camera system input current $\leq 890 \text{ mA}$ ✓ FCI 976 Accept

→ Camera system input current $> 890 \text{ mA}$ _____ Reject

Indicates

→ revision 11/78

Test conducted by G. Misera

Test-witnessed by K. W. Lam FCI 976

Date 10-16-78

5.0 TEMPERATURE TEST

5.1 TEST EQUIPMENT (or equivalent)

Leak Detector
Consolidated Electrodynamics Corp.
Model: 24-120B

Ionization Gauge
NRC Equipment Corp.
Type 551A-S

Ultra High Vacuum Ionization Gauge Control
NRC Equipment Corp.
Type 2207-03

Thermal Vacuum Chamber
Fairchild Imaging Systems
T-6186-1

Controller (2)
Alnor
Type N19

Digital Thermocouple Recorder
Kaye Instruments
System 8000

5.2 INSTALLATION

- 5.2.1 The camera, with the 25mm test lens and power supply, was installed on a copper thermal shroud and cold plate which was mounted within the vacuum test system. The cold plate and shroud were connected via feed-through ports to a liquid nitrogen supply. This system circulated liquid nitrogen through the cooling lines on the cold plate and thermal shroud wall. High temperatures were achieved by strip heaters secured to the copper shroud and cold plate.

- 5.2.2 The vacuum requirements were achieved by the use of mechanical vacuum pumps as well as oil diffusion pumps. Pressure measurements were made with an ionization gauge. Temperature measurements were made with thermocouples secured to the camera case, power supply and cold plate and were monitored and recorded with the use of a digital temperature measurement system.
- 5.2.3 Prior to the initiation of the environmental conditions, performance measurements in accordance with Section IV (Performance Tests during temperature) of QA Report No. 1615 Rev. B were made on the camera to provide a comparative basis for performance evaluation. During these tests, the camera was looking through the pyrex glass of the vacuum chamber wall. A photograph of the installation is included as Figure 12.

5.3 TEST PROCEDURE

- 5.3.1 With the camera de-energized, the chamber pressure was reduced to 1×10^{-6} torr.
- 5.3.2 When the pressure conditions had been stabilized, the cold plate temperature was increased to 131°F and maintained at this temperature for a period of six hours. Following the six hour exposure, the system was energized for a period of one hour and a series of comparative performance measurements were made in accordance with Section IV of QA Report No. 1615 Rev. B.

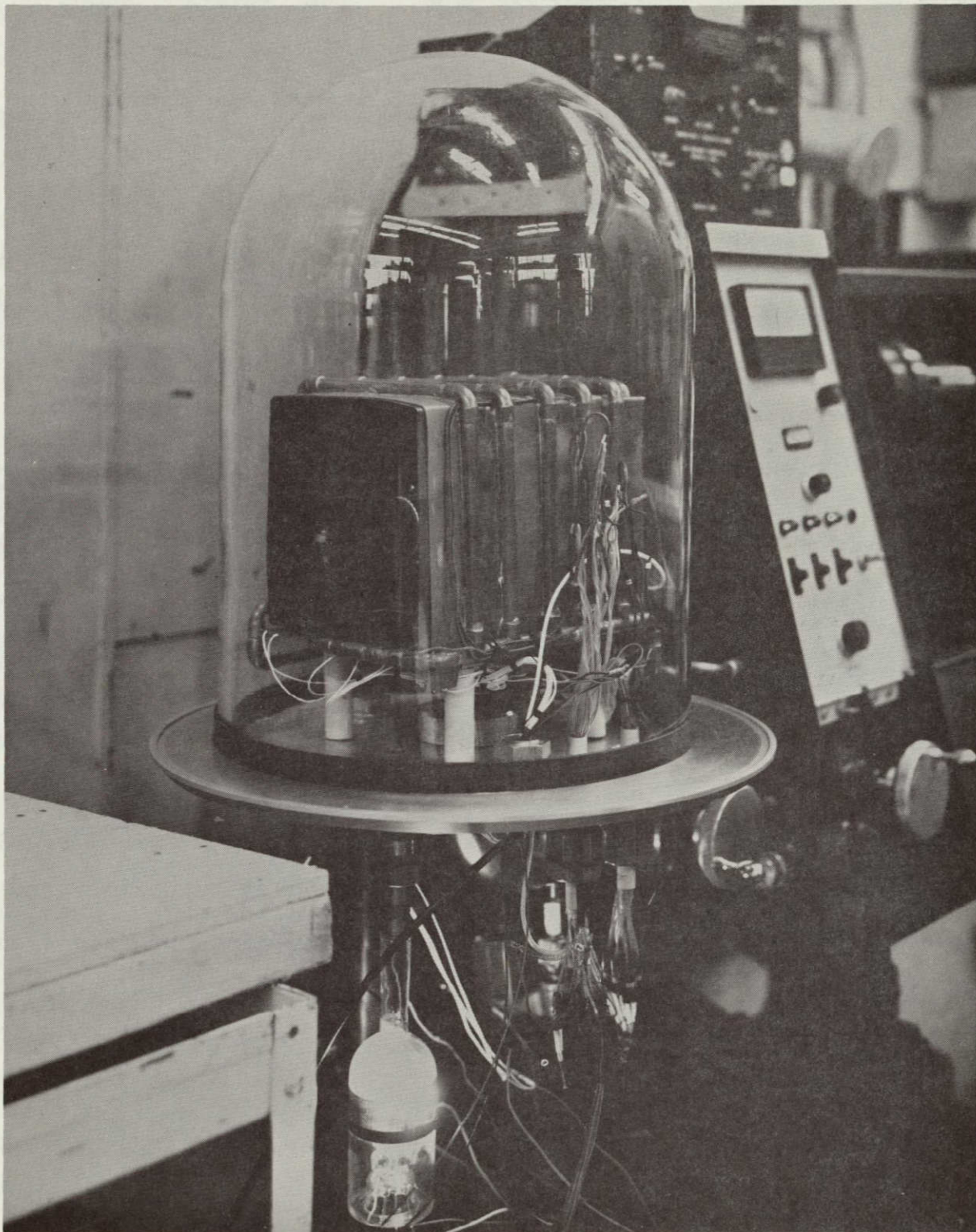


FIGURE 12. TEMPERATURE-VACUUM TEST SETUP

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- 5.3.3 The temperature of the cold plate was then increased to 160°F and the one hour operation period and comparative tests were repeated.
- 5.3.4 The temperature was again increased to 180°F and the one hour operation and comparative tests were repeated.
- 5.3.5 The camera was then de-energized and the cold plate temperature reduced to -65°F and maintained at these conditions for a period of two hours. Following the two hour exposure, the camera was energized for a period of one hour and a series of comparative measurements made in accordance with Section IV of QA Report No. 1615 Rev. B.
- 5.3.6 Further reductions in temperature were then made in 5°F increments and the corresponding performance measurements were made.
- 5.3.7 At the conclusion of the exposure period, the chamber and cold plate were returned to the standard conditions and the camera system was examined for evidence of damage as a result of the exposure. The camera system was then subjected to the performance test of Section III of QA Report No. 1615 Rev. B.

5.4 TEST RESULTS

- 5.4.1 Prior to the start of the test, the camera system automatic temperature control circuit was adjusted so that the cooler circuit maintained the CCD array at +3°C and the heater circuit maintained the CCD array at -20°C.

These limits were determined by operating the camera in a temperature chamber prior to the start of the test. A capacitor on the video board was also changed at this time to help eliminate array black clamp problems.

- 5.4.2 During the 131°F step when the camera power was turned on, the average temperature of the camera rose to 155°F. The vertical resolution had degraded enough to warrant stopping testing. In order to remedy this problem, the value of two potentiometers on the logic board were changed to minimize sensitivity of the vertical clock voltages with temperature. Testing was subsequently resumed and completed satisfactorily.
- 5.4.3 During the 180°F step, the operational period was limited to 50 minutes when the temperature of the power supply heat sink rose to 215°F.
- 5.4.4 The camera operation during the cold test was satisfactory during the -65°F step. After this portion of the test, the temperature was reduced in 5°F increments until the system ceased to perform satisfactorily.
- 5.4.5 At -75°F, the camera was checked for a 1 hour operational period. There appeared to be a horizontal sync problem and a low frequency ripple through the picture vertically at this temperature. The camera was subsequently removed from the setup and a resistor in the sync portion of the video board was decreased in value. The scene clamp

window potentiometer was also adjusted after measuring the scene clamp pulse timing.

- 5.4.6 When the camera was returned to the test setup and its temperature reduced to -75°F , the same problem as noted previously recurred. After examining the video, it was noted that the glitches that appeared on the sync pulses also appeared on every black to white or white to black transition in the video. It appeared that this problem might be an oscillation caused by an inability of the video output driver to drive its load (coax cable and video monitor). If the monitor was unterminated, the oscillations became worse thus indicating that the 75 ohm termination in the monitor helped dampen the oscillations. At this point, the problem was noted and the temperature was decreased further. Upon reading -90°F , the blacks in the scene were clipped. This was also noted and the temperature decreased until -112°F was reached. When the camera was turned on at this temperature, there was no video except for a pattern consisting of vertical noise. After approximately 1 minute the power supply current began to cycle (array heater cycling off and on) indicating that the CCD array had reached an acceptable temperature but the video had not changed. After 4 minutes the video appeared as it did at -90°F . The self-heating of the camera apparently allowed it to operate

after the 4 minutes. When the camera was brought to -115°F, it took 10 minutes to function as well as it did at -90°F. The test was stopped at this point and the camera was allowed to return to standard conditions.

- 4.5.8 An operational performance test in accordance with Section III of QA Report No. 1615 Rev. B was conducted at the conclusion of the temperature test. The results were recorded on the data sheets shown at the end of this Section.

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NASA/JSC ADVANCED DESIGN SOLID STATE
TELEVISION CAMERA SYSTEM
PERFORMANCE TEST DATA SHEET

Sheet 1 of 2

3.0 Camera Serial Number 6186-001

Lens Serial Number 13-260-041

Environmental Preconditioning Post Temp/ALT.

4.2 Light Level Calibration

b) Test pattern highlight brightness S02 f1

c) "f" number for one stop below saturation: f 5.6

d) $I_H = \frac{B \times 0.8}{4f^2 \times 100} = \underline{.032}$ fc (1 stop below saturation)

e) $f = \left(\frac{B \times 0.8}{4 \times 5 \times 10^{-2} \times 10^2} \right)^{1/2}$

B = 400 ft. lam.

f = f4

4.3 Resolution *

Horizontal Resolution 250 TVL/PH ≥ 200 FCI 976 Accept
 ≤ 200 _____ Reject

Vertical Resolution 375 TVL/PH ≥ 342 FCI 976 Accept
 ≤ 342 _____ Reject

4.4 Dark Current non-Uniformity* (.050v)

Video output non-uniformity ≤ 10 IRE units (71.4mV) FCI 976 Accept

Video output non-uniformity ≥ 10 IRE units (71.4mV) _____ Reject

4.5 Signal-to-Noise Ratio

Peak-to-peak highlight video signal V_p .760v

* Record observed values

Peak-to-peak temporal noise variations N_{p-p} 0.012 ✓

$$SNR = 20 \log (6 V_{p-p} / N_{p-p})$$

= 51 dB

≤ 40dB ✓ FCI 976 Accept

> 40dB _____ Reject

4.6 Automatic Light Control (ALC)

ALC voltage from step (a) 2.4 ✓

ALC voltage within ±5% of step (a) _____ Accept

ALC voltage not within ±5% of step (a) FCI Reject

4.7 Output Video Format

Composite video polarity, black negative ✓ FCI 976 Accept

black negative _____ Reject

Blanked picture signal with setup, V_{pp} = 0.680 V;

0.614V to 0.814V ✓ FCI 976 Accept

<0.614V to >0.814V _____ Reject

Sync signal (from 0VDC Ref.) V_s = 0.280 V

0.236V to 0.336V ✓ FCI 976 Accept

<0.236V to >0.336V _____ Reject

Setup, blanking level to ref. black level 7 IRE units*

*Passes spec until 25% average picture level

7.0 to 8.0 IRE units ✓ FCI 976 Accept

<7.0 to >8.0 IRE units _____ Reject

Sync signal waveform per EIA RS-170 ✓ Accept

_____ Reject

4.8 Power Supply

Power supply input voltage ✓ FCI 976 28VDC

Camera system operates at 24VDC and 32VDC ✓ FCI 976 Accept

Camera system does not operate at 24VDC and 32 VDC ✓ Reject

→ Camera system input current ≤ 890mA ✓ FCI 976 Accept

→ Camera system input current > 890mA _____ Reject

Indicates

Test conducted by E. Misura

→ revision 11/78

Test witnessed by K. Llan

FCI 976

Date 12-1-78